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FINAL TECHNICAL REPORT
GIT/EES PROJECT A–3078

CONCEPTS FOR THE NETTING OF SELECTED BISS SENSORS

By

F. R. Williamson, E. F. Greneker, and N. C. Currie

Prepared for

AIR FORCE SYSTEMS COMMAND
ELECTRONIC SYSTEMS DIVISION
HANSCOM AFB, MASSACHUSETTS 01731
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Under

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February 1983

GEORGIA INSTITUTE OF TECHNOLOGY

A Unit of the University System of Georgia
Engineering Experiment Station
Atlanta, Georgia 30332

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This report summarizes the results of a study to develop concepts for the netting of radar and non-radar sensors into a single communication and display system. The basic concept involves the development of a digital communications interface for each sensor which communicates with a central netting computer and a real time color, scenario map display. The concept involves minimal modifications to the sensors and utilizes currently available computer technology to provide the sensor netting and display

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20. functions. Interfaces are proposed for the BISS SPCDS sensor system, the FIDS sensor system, the AN/PPS-15 radar, and the AN/PPS-5 radar. Suggested real time display scenarios are given, and the results from a survey of currently available digital color displays is presented.

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SECTION 1
INTRODUCTION

1.1 SCOPE

This report summarizes the results of a study performed to determine the required properties of a command and control system which will allow different generic types of physical security sensors to be combined into a single display format. The primary types of sensors considered may be separated into four generic classes: (1) exterior point sensors as is illustrated by the Base Installation Security System (BISS) Small Permanent Communications and Display Segment (SPCDS), (2) interior point sensors such as those used currently with the U. S. Army Facility Intruder Detection System (FIDS), (3) limited area sensors such as the AN/PPS-15 radar system, and (4) wide area sensors such as the AN/PPS-5 radar system. The methodology applied during the study involved defining the salient characteristics of each class of sensor, developing concepts for interfacing each sensor type to a digital communications link, designing the data processor system architecture including the necessary algorithms which must be executed, and determining the major characteristics of a real-time computer-animated display that will enhance operator efficiency in interpreting information from many sensors of different generic types.

1.2 BASE SECURITY - A STATEMENT OF THE BASIC PROBLEM

Physical security is becoming more of a concern within the DoD community because of the increasing cost, complexity, and capabilities of modern weapon systems which result in them being valuable targets for terrorist groups, espionage activities of foreign powers, and demonstration activities for anti-establishment movements. Because of the current extremely high cost of labor in the United States, protection of these sites using security guards can account for a large portion of the total weapon cost for a system having a long operational life. Accordingly, it is desirable to take advantage of current sensor/surveillance system technology in order to reduce the total manpower requirements for system protection and to make the remaining personnel more effective.

Sensor technology and security systems are currently available to provide assistance to security personnel in the detection and localization of potential intruders, but in general these systems have a number of problems including: (1) current sensor systems tend to be extremely labor intensive and require continuous operators (for example radar displays, TV displays), (2) most of the current systems in development have unacceptable levels of false or nuisance alarms without easy methods of verification of potential intruders, and (3) single technology sensors which are currently used are more easily fooled by potential intruders than multiple sensor technology types which can also help to reduce nuisance alarms.

A netted security surveillance system can provide a solution to these problems by allowing multiple sensor types to be tied together into a single display system which can provide sophisticated processing to reduce nuisance alarms and improve target detection capabilities. The desired features of a netted system are listed below.

A netted security system should:

- Allow the combined operation of several sensors as a common surveillance system.
- Match the threat scenario matrix with an optimum distribution of sensor-surveillance capability.
- Allow targets to be monitored via multiple sensor technologies to provide verification techniques and improve the overall detection and false alarm characteristics of the netted system.
- Provide operator assistance in the form of
  - Automatic operation of equipment,
  - Automatic status check of system,
  - Automatic target detection and tracking,
  - Threat evaluation of detected targets, and
  - Multiple sensor information (radar and fixed location sensors) combined into a common scenario-map presentation.

The general scenario of potential threats along with the applicable sensors are given in Figure 1. The netted system should provide for the inclusion of all these sensor types to be integrated so that their outputs can be monitored on a single display. Unfortunately, most sensors under current development have no provisions for interfaces to a centralized system, and those that do generally have inadequate input amd output

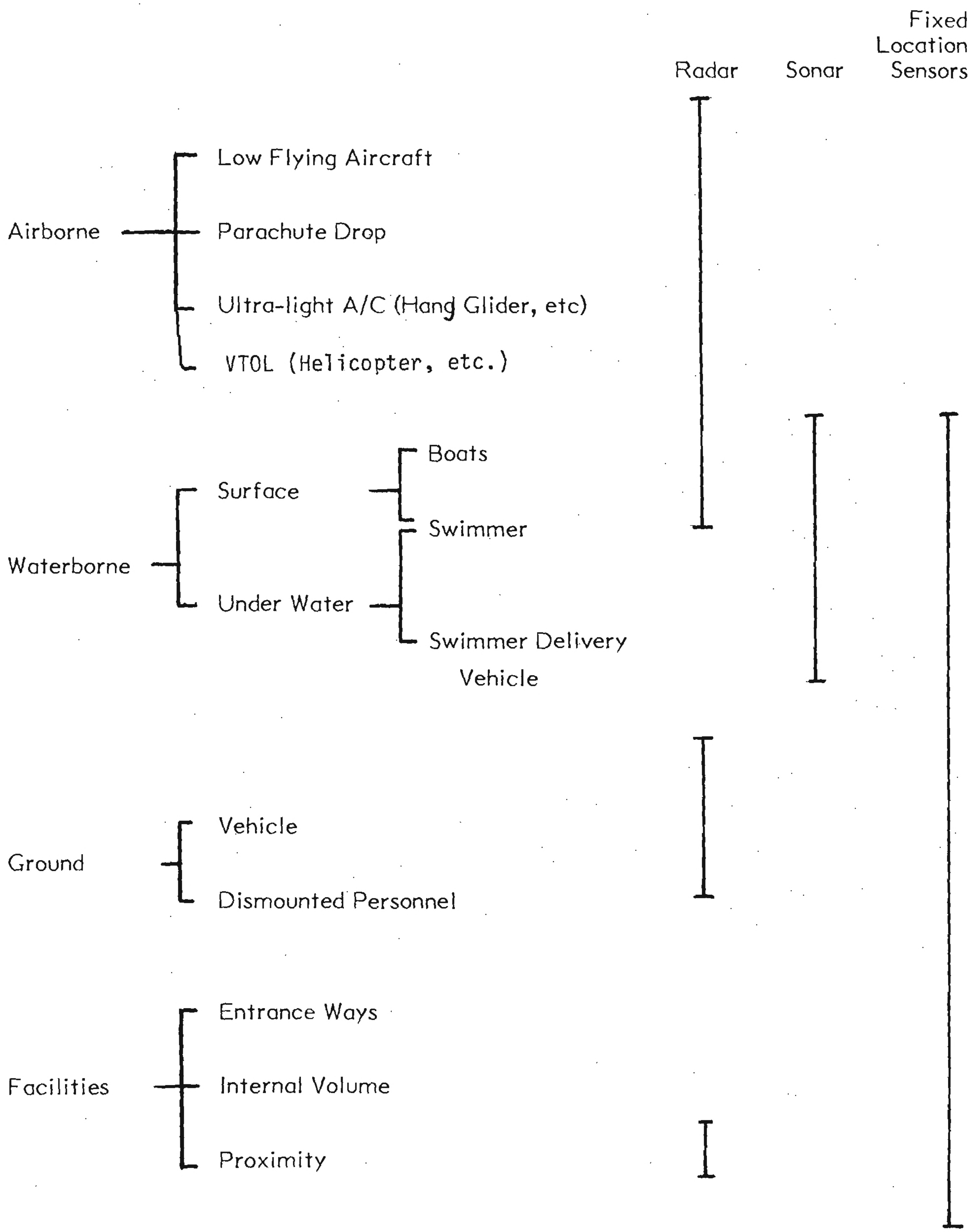


Figure 1. General threat scanario matrix.

(I/O) capabilities for a netted system. Thus, it is imperative that new sensors include such a capability and that interfaces be developed for currently available sensors.

1.3 STUDY GOALS

Radar has long been known to be an efficient surveillance device for monitoring large areas for moving vehicles and dismounted personnel. With the increasing cost of security personnel, radar cannot be used for physical security applications in the conventional mode with a single operator for each radar scope, or the operating cost will be excessively high. Operator efficiency decreases during long radar display observation. Therefore, techniques and algorithms are being developed and implemented to automate as many of the target detection, identification, and assessment functions as practical.

Multiple radar sensors can be used to overcome the surveillance limitations inherent in a single radar due to radar scan speeds, sector scan limits, terrain masking, etc. Although multiple radar sensors can provide much better surveillance coverage of a given area than a single radar, the data processing load and the number of operators required could increase in proportion to the number of radar sensors. Advances in distributed processing technology and sensor netting techniques, however, make it possible to employ multiple radar sensors integrated with other (acoustic, seismic, etc.) sensors in a single netted configuration that provides a high degree of automated target processing and correlation so that all surveillance sensors can be monitored by one operator.

Non-radar sensors (seismic, acoustic, etc.) are more practical than radar sensors for monitoring certain areas in many security/surveillance applications. The overall surveillance system effectiveness can be increased by integrating these non-radar sensors with the radar sensors so that the total area under surveillance can be monitored by a single operator.

This research effort is directed toward defining concepts for netting (combining) ground surveillance radars and point sensors to present intrusion data on a situation map display so that all sensors for the entire surveillance area can be monitored by one operator. The principles for netting ground surveillance radars draw heavily upon the techniques and principles that were developed and tested by Georgia Tech for the MX-missile program.[1,2] The fixed sensor netting technology is drawn from existing system concepts wherever possible.

The netting concepts considered in this study will accommodate (1) existing sensor systems and (2) desirable prototype technologies. The application configurations must provide a cost-effective solution to the limited netting configurations (possibly with one radar) and be expandable to the projected maximum capacity system using several radars and many point sensors. The netting concepts are directed toward applications involving rapid deployment for surveillance of temporary installations and surveillance of permanent base installations. The concepts investigated address sensor availability, preferred netting configuration, possible target detection and threat assessment algorithms, and data link and display concepts necessary for meeting the netted surveillance system goals.

1.4 SUMMARY

The study of concepts for the netting of selected BISS sensors was based on an assumed scenario that would employ the largest anticipated number of sensors. The assumed scenario is defined in Table 1, and a possible deployment configuration is shown in Figure 2.

TABLE 1. SCENARIO FOR NETTED RADAR/FIXED SENSOR CONCEPT STUDY

Protected Assets:	Assembly of Vehicles and/or Support Shelters
Area Perimeter:	9000 Meter Circumference Maximum
Fixed Sensors:	- To Protect Shelters and Vehicles - To Monitor Remote Sites (Roads, Radar Sites, etc.) - Types: Seismic and Magnetic - To Detect (and Discriminate): Vehicles and Man - 320 Fixed Sensors Maximum in a Net
Radar Sensors:	- Maximum of 2 Area Surveillance Radars (AN/PPS-5) Capable of Remote Netted Operation Via RF Data Link - Possible Gap Filler Radars: - FOLPEN - Foliage Penetration Section Surveillance Radar (4 Maximum) - AN/PPS-15 - Sector Surveillance Radar
IFF Transponders:	For Identifying and Vectoring Friendly Forces (20 Maximum)
System Setup Time:	2 Hours

The study was separated into four distinct tasks that could be performed serially. First, data on the specific characteristics of a typical example of each of the generic

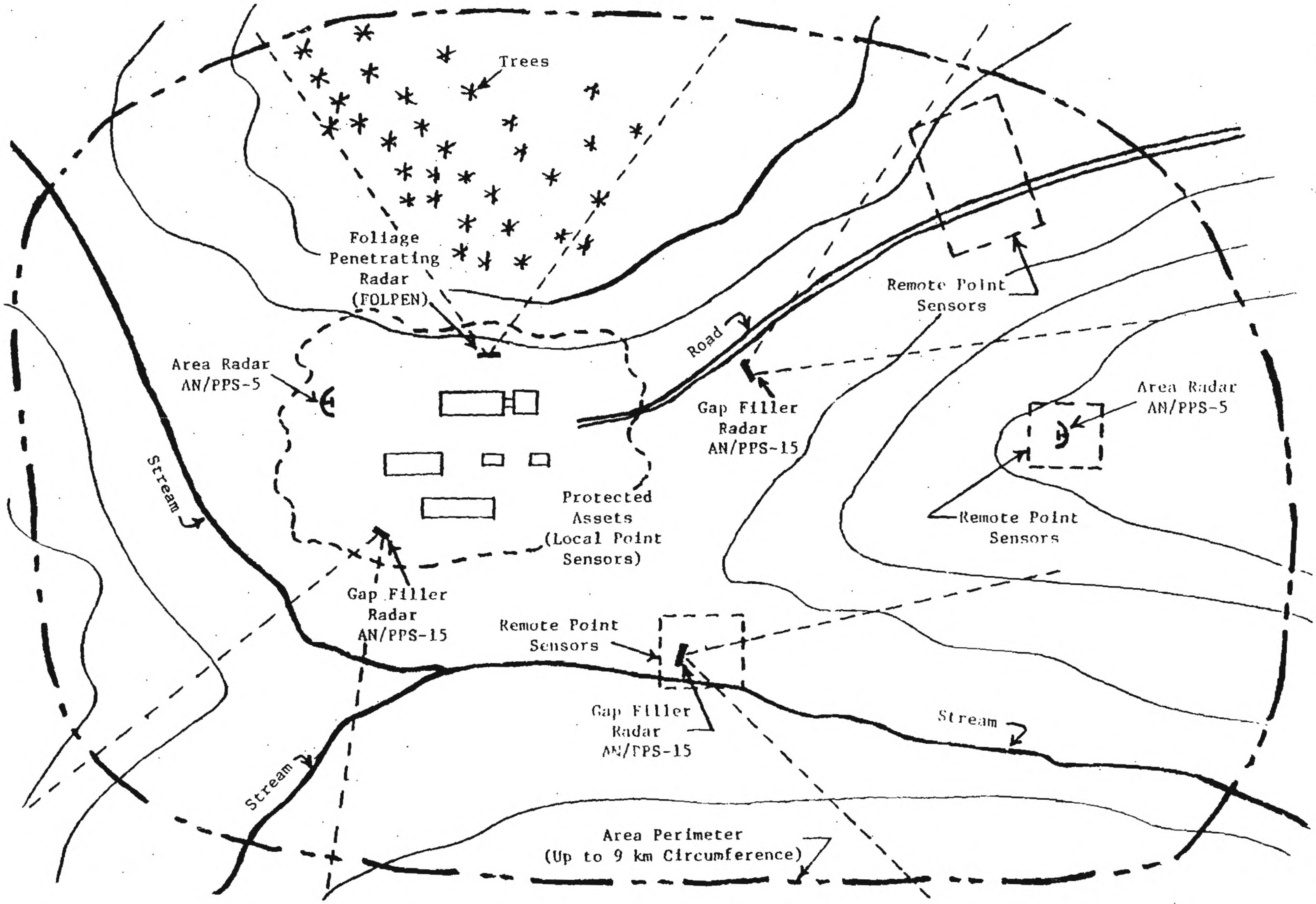


Figure 2. One possible deployment configuration for the assumed sensor scenario.

types of sensors were gathered. The specific sensors chosen included the BISS SPCDS system, the FIDS system, the AN/PPS-15(B) radar, the Foliage Penetration (FOLPEN) radar, and the AN/PPS-5 radar. After the characteristics of each system were defined, conceptual designs were formulated for sensor interfaces that would allow all information gathered by each sensor to be transmitted to a digital communications system. The sensor systems are described in Section 2 and Appendix A.

Then, the system architecture for the communications and data processing system was structured around a distributed processing concept to maximize the system flexibility and minimize cost. Basically, the concept involves using microcomputers to perform first-level signal processing at a site near the sensors so that the data formats can be standardized, and the communication link data rates can be decreased. The system signal processing algorithms were based on experience gained during the development of a netted radar physical security system for the MX program.[1,2,3]

The characteristics of the communication link were based on a current Tri-Service specification for RF transmission links (SEIWIG-005).[3] An RF data link was chosen because it will facilitate rapid deployment of remote sensors (for the bare base situation) and it will handle high data rates from the radar sensors. Exceptions to the SEIWIG-005 specification may be necessary because of the longer data words or higher data rates required to transmit radar data. Proposed interface descriptions for selected sensors are included in Appendix B.

Once the system architecture was defined, display concepts were formulated to allow maximum use of the potentially large amount of data to be displayed to inform the physical security operator of the status of the protected area without overwhelming him with information. This part of the study drew upon the experience gained during the development of a real time computer-enhanced color display for the Target Detection Unit developed under the Waterborne Intrusion Detection Segment (WIDS) program.[4,5] This part of the study also included a survey of available computer-enhanced displays which is included in Appendix C.

A specific design for the AN/PPS(B) radar interface to the netted system is given in Appendix D. Appendix E discusses some of the hardware considerations for the netted digital processor.

The following sections of this report discuss the details of the results of the four tasks performed.

SECTION 2
CONCEPTS FOR NETTING RADAR AND FIXED SENSORS

2.1 PROPERTIES OF A NETTED SYSTEM

The netted sensor concept came about from attempts to overcome some of the limitations of previous security sensors. The two major problems with such previous sensor systems were that they required too many personnel for operation over large areas and they produced too many false or nuisance alarms. Another factor which has been encountered for high data rate sensors such as radar is operator fatigue. Typically radar operators observing a number of targets on a display will remain fully alert for only a few minutes at a time. Thus, the netting concept is an attempt to use modern computer technology to reduce the number of personnel required to operate a security system, reduce false or nuisance alarms, and eliminate operator fatigue by displaying only targets that have a high probability of being threats.

A considerable amount of data processing and complex algorithms are inherent consequences of netted-sensor concepts. One way to simplify the processing problem and, thus, lower the cost is to use so-called distributed processing techniques. This simply means that, rather than using one large high speed computer to do all the processing, the processing task is broken up into several smaller components which can be handled by smaller less costly computers. The new microcomputer technology makes this highly feasible. Another advantage of distributed processing is the possibility of locating the first-level processor near the sensor. In the case of a radar, initial processing near the radar sensor can reduce the data rates from many megahertz to a few kilohertz, thus greatly decreasing the cost and complexity of the data link which carries the data to the central processing and display unit.

The netted system can reduce false or nuisance alarms in two ways. First, if two or more similar sensors detect the same target, then the effective increase in data rate allows the use of more integration to reduce false alarms and more sophisticated algorithms to eliminate nuisance alarms. Second, if two generically different sensors detect the same target, the proper correlation of target reports from the two sensors can greatly enhance the likelihood that displayed targets are a threat.

Once a threat is detected, the outputs from multiple sensors can be used to build a threat track so that the intended destination can be predicted to aid direction of security forces to intercept an intruder. This is much easier to achieve through the use of wide area radars which provide continuous coverage of an area, but it can also be achieved to some extent with limited area radars and point sensors.

To achieve the desired functions discussed above, the netted system should have certain properties. These include modular components to facilitate repair of the units, expandability so that additional sensors can be added, and flexibility so that new processing techniques can be implemented as they are developed. The system should be able to incorporate all types of sensors currently being developed for physical security applications, and the display should present system status and provide threat information to the operator in as simple a manner as possible. Furthermore, the operator should be able to interrogate those sensors which can respond to obtain additional information or change sensor parameters. The following pages will discuss methods for achieving these parameters.

2.2 CURRENT SENSOR PROPERTIES

Several sensor technologies that will be useful in a netted surveillance system are available off-the-shelf, and several of these sensors may be made more useful by including them in a netted system. Available sensors reviewed for this study included radar sets, fixed sensors, and fixed sensor systems. The radars considered for this application included the FOLPEN radar system, the AN/PPS-15 short-range sector-surveillance radar, and the AN/PPS-5 (or the AN/PPS-5 Modified) area-surveillance radar system. These radars were considered to have quailities useful in any netted radar-fixed sensor surveillance system. A summary of the operating parameters for these three systems is given in Table 2, and descriptions are provided in Appendix A.

The FOLPEN system operates within the UHF frequency band and can provide surveillance of moving vehicles and personnel in regions covered with heavy foliage. An advanced design model of this radar system is currently under development. A summary description of this radar is included in Appendix A.

The AN/PPS-15 radar is a short-range sector-surveillance radar transmitting at X-band frequencies and is capable of detecting moving vehicles and dismounted personnel in open terrain at distances of 3 to 4 kilometers. This system is normally used to detect and track single targets under operator control. An improved version of this radar system (the EPSD - Exterior Perimeter Surveillance Device) is being developed and is to include a netting interface. A summary description of this radar is also included in Appendix A.

TABLE 2. RADAR SPECIFICATIONS

TYPE	AN/PPS-5 (MODIFIED)	FOLPEN	AN/PPS-15 (B) (EPSD Mod)
DESCRIPTION	PULSE DOPPLER COHERENT ON RECEIVE	CW-DOPPLER	FM-CW
MAXIMUM DETECTION RANGE (0.5 SQ. METER TARGET)	APPROX. 6 KM	APPROX. 1.5 KM	APPROX. 1.5 KM
FREQUENCY	16 - 16.5 GHz	435 MHz	10.25 GHz
POLARIZATION	LINEAR HORIZONTAL RIGHT HAND CIRCULAR	-	LINEAR VERTICAL
ANTENNA AZIMUTH BEAMWIDTH ELEVATION BEAMWIDTH	PARABOLIC 0.7^0 3.5^0	BISTATIC - DIPOLE ARRAYS 120^0 20^0	SLOT ARRAY 5.6^0 10^0
PEAK POWER AVERAGE POWER PULSE WIDTH PULSE REPITION RATE	1 KW 0.67 W 0.25 µSEC 2 KHz	20 W 10 W - -	94 MW 45 MW - -
BAND WIDTH RF IF	 500 MHz 4 MHz	 50 MHz 60 Hz	 - -
MAXIMUM INSTRUMENTED RANGE	10 KM	1.5 KM	3 KM
RANGE RESOLUTION	50 METERS	30 METERS	35 METERS
NUMBER OF RANGE BINS INTEGRATOR TIME CONSTANT VELOCITY FILTER CUTOFF FREQUENCY CUTOFF VELOCITY	200 16 MS 80 TO 160 Hz 0.7 TO 1.5 M/S	3 - ADJUSTABLE POSITIONS (EXPANDABLE TO 10 BINS) 6.5 TO 10 SEC - .2 M/SEC.	7* - - 0.805 KM/SEC.
AZIMUTH COVERAGE TYPE OF SCAN AZIMUTH RESOLUTION	360^0 MECHANICAL - AZIMUTH 0.7^0	120^0 MONOPULSE-MULTIPLE REC.ANT. 10^0	360^0 MECHANICAL - AZIMUTH $\pm 0.6^0$

*RANGE BINS AT 50 METER SEPARATION REFERENCED TO MANUALLY SET RANGE GATE.

An area surveillance radar has been included in the design scenario of the maximum capacity system. This radar includes the following properties: (1) a 360 degree surveillance sector, (2) a track-while-scan capability, (3) an extended detection range for large area coverage, and (4) a moving target indication (MTI) signal processor. A modified AN/PPS-5 radar was selected as being representative of this generic radar class. This modified radar system was used in the Long range Area Radar for Intrusion detection And Tracking (LARIAT) netted radar surveillance system developed by Georgia Tech to demonstrate the feasibility of a wide-area base security system for the MX-missile program. A brief summary of the LARIAT netted radar system appears in Appendix A.

The radar sensors considered in this concept definition study have characteristics thought to be needed for the netted security system. The radar sets described represent the capabilities of current technologies. The netting principles developed in this study are also be applicable for other radar sensor designs.

The area surveillance radar provides the basis for a wide area security system for use in the maximum capacity netted surveillance application. This radar sensor should have: (1) a wide angle scan (preferably 360 degrees), (2) a moving target signal processing system, (3) a track-while-scan capability, and (4) a capability to operate remotely without operator attendance. The area surveillance radar will typically be mounted on a tower or on high ground to obtain a maximum unobstructed surveillance area.

The sector surveillance radars represent a class of short range sensors for detecting moving personnel and vehicles. These sensors must also include: (1) a moving target processor, (2) a track-while-scan mode, and (3) facilities for remote operation. Neither the AN/PPS-15 radar nor the FOLPEN radar currently meet the requirements for remote operation. A remote netting interface for these two systems is planned, and a proposed interface definition for this application is included in Appendix B. This class of radar will be used as the primary sensors in limited radar surveillance applications and as gap filler sensors in areas not easily monitored by the area surveillance radar systems.

Radar has long been recognized as an efficient area surveillance device. A radar sensor (or group of sensors) can provide a unique overview of the surveillance area. The use of multiple radars having overlapping coverage can reduce the problems encountered by terrain masking or shadowing since one radar can be positioned to view areas hidden from other radar sets. The gap filler radar is a special application of this concept.

The radars considered for this application use MTI processing to improve the target detection process by separating small moving targets from large stationary ground clutter (such as found in the radar returns from trees, rocks, buildings, etc.). While this signal processing method can significantly improve the sensitivity of a radar to moving targets, it depends on target movement radially toward or away from the radar. Tangential movement of the target is not detected by an MTI radar since no Doppler frequency return is produced. In this case, multiple radar sensors will eliminate many of the dropouts since it is much harder to move tangentially to a number of radars critically positioned.

Fixed sensors have been effectively netted in at least two systems: (1) the Facility Intrusion Detection System (FIDS) and (2) the BISS Small Permanent Communications and Display Segment (SPCDS). Since these systems have successfully interfaced fixed sensors of many different technologies, they were considered as the basis for the fixed sensor sources in this study. Descriptions of these two fixed sensor systems are also included in Appendix A.

2.3 NETTED RADAR-FIXED SENSOR SECURITY SYSTEM CONCEPTS

2.3.1 STUDY GUIDELINES

This investigation was directed toward development of netting concepts to (1) meet the projected requirements for future automation of target detection, track management, and threat assessment (a maximum capacity system with wide area radar surveillance), and (2) meet the current system needs for netting a limited number of personnel detecting radars (one or more) and a group of fixed sensors with a common operator/display system. Concepts for current system needs were primarily directed toward applications that do not require a full radar surveillance capability. Such a reduced capacity system may provide only modest computer assistance to the operator and may include only sector radars having limited overlapping coverage. Concepts meeting the current security system requirements will be expandable to the full system capability.

The design philosophy also included a definition of the desired target handling priorities for the netted system. The following rules were factored into the signal processing hierarchy and algorithms.

a. All radar targets shall be detected automatically. This is necessary due to the large target load (large number of targets) that a radar or group of radars presents to a single operator.

b. Targets may be detected by two or more radars when the radar sets are located to have overlapping coverage. The maximum capacity netting system should include automatic correlation of targets detected by radars having overlapping coverage.

c. The same target may be detected by both radar and fixed detectors. Provision must be included in the signal processing algorithms to correlate radar target detections with those obtained from the fixed sensor arrays.

d. Radar detections must be converted to a common coordinate system to facilitate automatic target tracking, target assessment, and display. Radar systems provide target data in a polar coordinate system, but a map grid system provides a more efficient means for developing the target handling principles described above. The X-Y coordinate system is very compatible with automatic analysis by computer, and this approach was adopted for this concept investigation.

e. The detection rate of radar targets must be controlled to prevent data link and computer saturation. This process was addressed through radar preprocessing algorithms (processing algorithms located with the radar sensor) such as Constant False Alarm Rate (CFAR) thresholding, target verification algorithms, and target track algorithms.

f. The radar sensors must include self-test functions to ensure correct operation and detect degraded sensor performance. Methods must also be included to detect tampering and indicate the use of electronic countermeasures. The radar sensor status indicatation modes parallel the capabilities of the fixed sensors that are used in the FIDS and SPCDS netted systems.

2.3.2 NETTED SENSOR SYSTEM DESIGN

A number of proposed requirements have been set forth for a netted radar-fixed sensor surveillance system, and a design philosophy has also been defined to guide the concept investigations. The basic netted security system approach uses a number of remotely operated radars that are connected to a central netting computer via a two-way data link. A significant amount of radar signal processing and radar target processing at the remote radar sites is necessary to control the information rate on the data link channels. A general block diagram of the netting concept is illustrated in Figure 3. The netting computer contains: (1) the interface with the remote radar sets and the fixed sensor system, (2) algorithms for target detection by all sensors, and (3) the two-way interface to the operator-display system. For the maximum capacity system, the netting computer will contain the algorithms for automatic target declaration, tracking, and assessment.

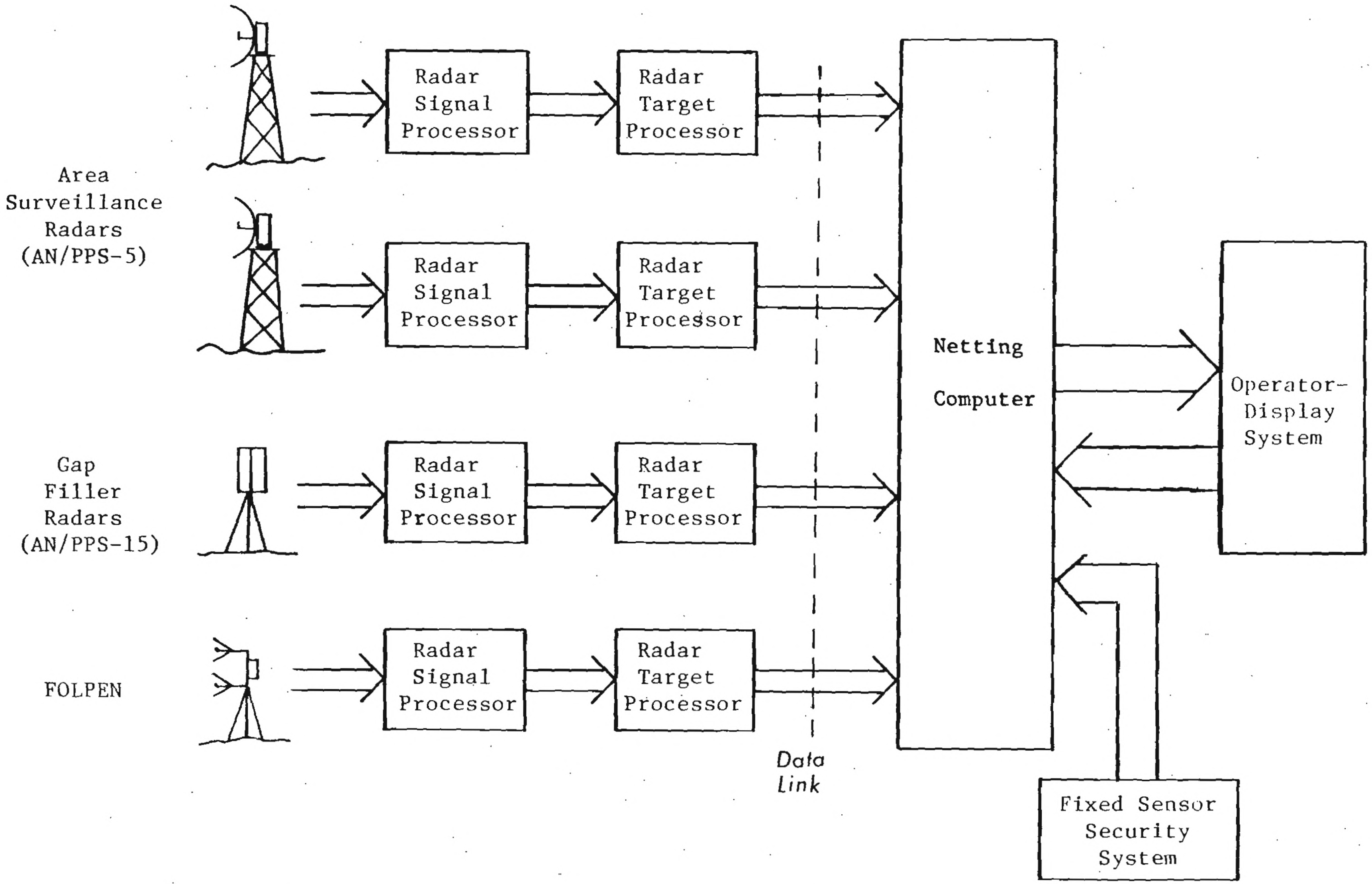


Figure 3. Netted radar fixed sensor system concept.

A rapid deployment requirement has been assumed for the netted radar-fixed sensor surveillance system. The principles included in the netting concepts apply equally well to permanent installation security systems as to temporary installation systems requiring a fast set-up time. One major impact of the fast deployment requirement is that it establishes a need for a radio frequency (RF) data link between the netting computer and the remote radar sensors. This capability will be specified in the design and will adhere to available RF data link specifications where applicable.

Rapid deployment requirements also imply a high degree of portability in the radar sensors and influence the manner in which the sensors are mounted. Both the FOLPEN and the AN/PPS-15(B) sector surveillance radars are portable and can be routinely set up in a relatively short time on a short tripod by one or two personnel. The high degree of portability of the sector surveillance radars is ideal for this application, but it imposes some unique requirements in the area of tamper detection. These requirements are discussed in more detail in paragraph 2.3.7.4.

The area surveillance radar will typically require a much higher mounting support to ensure maximum surveillance of open and unobscured terrain out to the instrumented range of the radar. This implies that this radar should be elevated above the local tree line to ensure a clear view of the surveillance area. While hilltop positions can provide good vantage points for this purpose, it will frequently be necessary to locate this radar on a tower. The AN/PPS-5 modified radar (considered here as having representative properties of an area surveillance radar system) was successively deployed on a trailer-mounted telescoping tower to heights of 100 feet during a Georgia Tech field trip for clutter measurements at a number of desert sites. The unit used for these field measurements had a five section tower mounted on a trailer and stored in a horizontal position (25 feet long in the retracted condition) during transportation and installation or servicing of the radar set. The radar was transported as subassemblies in storage containers and could be assembled on the tower by a minimum of two persons in less than one hour. The trailer mounted tower had built in winches for rotating the tower to a vertical position and for extending the sections to a maximum tower height of 100 feet. The tower was stabilized by leveling pads on the trailer and a three-wire guy system attached to screw anchors placed in the ground. With careful design, this system can be self-contained with the radar storage containers and a portable power source (for the tower erection system) mounted directly on a single trailer. A total deployment time of less than one hour (including installation of the tower guying system) should be achievable by a three- or four-man crew by using parallel efforts for installation of the radar on the tower and installation of the ground anchors and the guying system.

2.3.3 NETTED RADAR DEFINITIONS

Several complex concepts are addressed in the discussion of netted radars and fixed sensors. The following definitions will be adhered to for the remainder of this report to ensure a clear understanding of the concepts:

a. Occupied Resolution Cell (ORC): A range-azimuth cell having a radar return greater than the detection threshold.

b. Potential Target Verification: The algorithm for associating and correlating ORC's produced by the same potential intruder.

c. Target Declaration: The establishment of a target track for a series of associated ORC's that represent a potential moving intruder.

d. Initialization Criteria: The minimum number of associated ORC's within a fixed time period or a fixed number of scans required for target declaration.

e. Termination Criteria: The threshold number of associated ORC's (within a fixed time period or a fixed number of scans) below which a track is terminated.

f. Split Track Algorithm: When two targets moving along the same path diverge to form separate paths, a new track will be generated for one of the paths. Correspondingly, converging paths will cause one track to be cancelled.

g. Constant False Alarm Rate (CFAR): An algorithm for adjusting the detection threshold for a given range-azimuth cell based on the events in adjacent resolution cells.

h. Beam Splitting: An algorithm for estimating the azimuth position of a target return to increase the angular pointing resolution of the antenna.

2.3.4 MULTIPLE TARGET DETECTION CONCEPT

A basic reason for netting a number of radar sensors with a group of fixed sensors is to allow all surveillance information to be routed to a common processing/assessment system with a single operator-display interface. This system concept may have a number of points of overlapping coverage (between radar units as well as between radars and the fixed sensor array) to increase the effectiveness of the surveillance. Several advantages of overlapping radar coverage have already been mentioned. These include reducing the effects of terrain masking, minimizing target dropouts due to tracks that are tangential to the sensing radar, and using special radar properties of the FOLPEN (for searching areas in heavy foliage). Another obvious advantage is having knowledge that a potential intruder is approaching a fixed sensor.

The concept of overlapping coverage is illustrated in the diagram in Figure 4. The scenario depicted in this drawing shows two area radars (Radar 1 and Radar 2) being used with 4 sector surveillance radars. While this scenario would be considered the maximum capacity system, it illustrates the situation where a single target is simultaneously visible to three different radar sensors. The geometry for reporting the position of the target in this figure is seen to require a unique angle and range for each of the radars. Each radar typically detects targets (internally) in a polar coordinate system that is referenced to the location of the radar and to some arbitrary pointing angle. This example demonstrates the need for each ORC report to be expressed in Cartesian coordinates. The conversion can be made at the target preprocessor located at each radar site if the radar location is known (in Cartesian coordinates) and the pointing angle of each set is known. This requires that the position and reference pointing angle be furnished to the target preprocessing computers as part of the initialization process. These requirements will be addressed further in the section defining the characteristics of the control and data links connecting the radar sites and the central netting computer.

2.3.5 TARGET HANDLING PHILOSOPHY

The majority of the "reports" processed will be derived from the radar sensors due to the large area under surveillance. The large amount of expected personnel activity in the surveillance area supports an option for an identification friend or foe (IFF) transponder system. A basic principle of the target handling philosophy is that the radar surveillance system can provide a warning for the fixed sensor array. Under these ground rules, an intruder's approach to a secure area should be automatically tracked by the netted radars, and any alarm from a fixed sensor must be considered a <u>definite threat</u> if it is a continuation of a radar track.

The ORC processing priorities for a combined radar-fixed sensor system are outlined in Figure 5 in a manner similar to the radar only case previously illustrated in Figure 4. Here, the potential intruder detected by the three radars is shown to have triggered a fixed sensor (or sensors). The radar data are first analyzed by the netting computer to correlate the ORC reports and possibly reduce any redundancy that would tend to load the automatic processing algorithms within the netting computer. This recognizes that ORC reports will be made from <u>different</u> radar sensors when overlapping radar coverage is used. It is also recognized that location errors may exist in the ORC reports from each radar due to limitations in the range and azimuth resolution of the radar sensors. The ORC correlation process can be enhanced by filtering and estimating

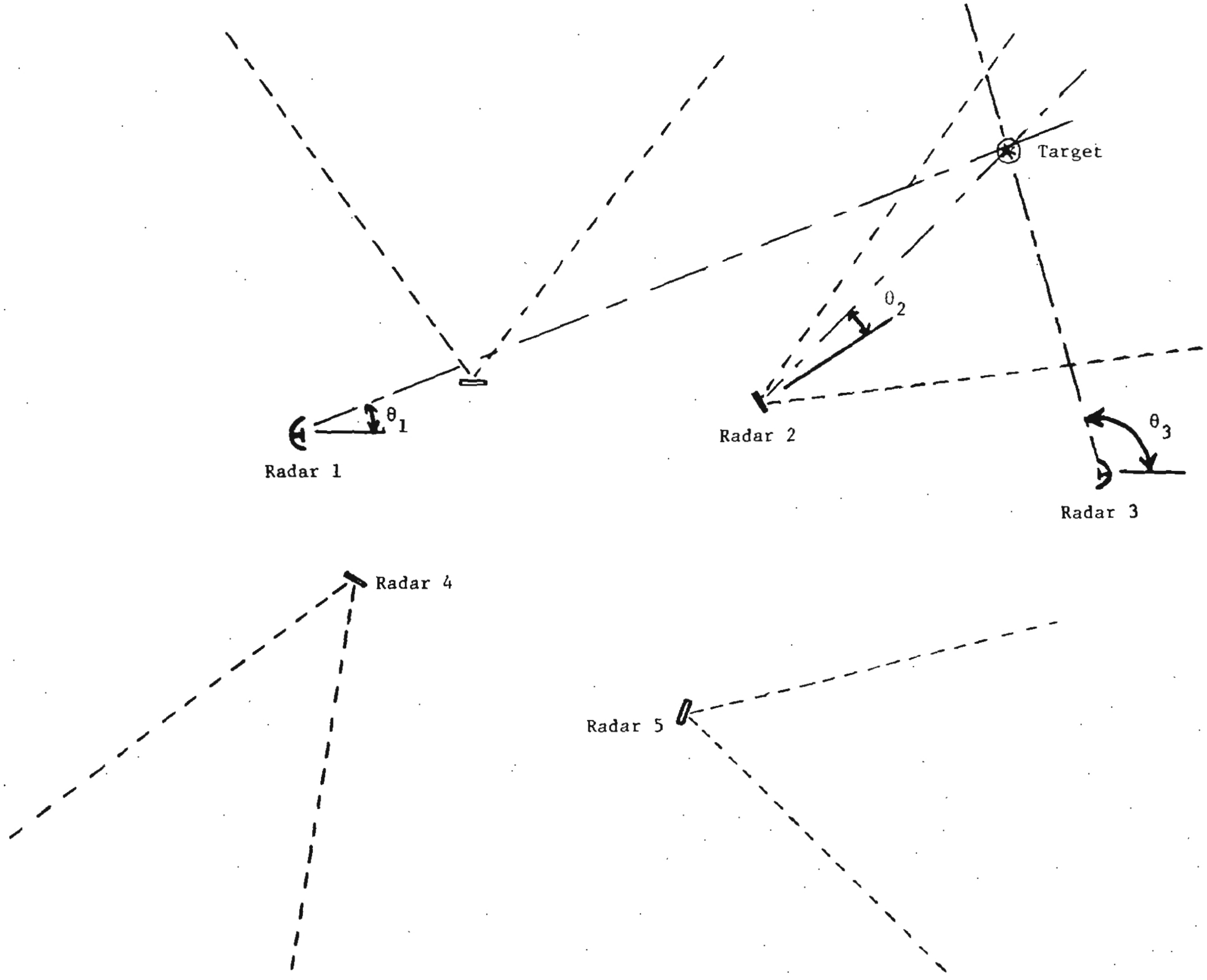


Figure 4. Multiple radar detection concept.

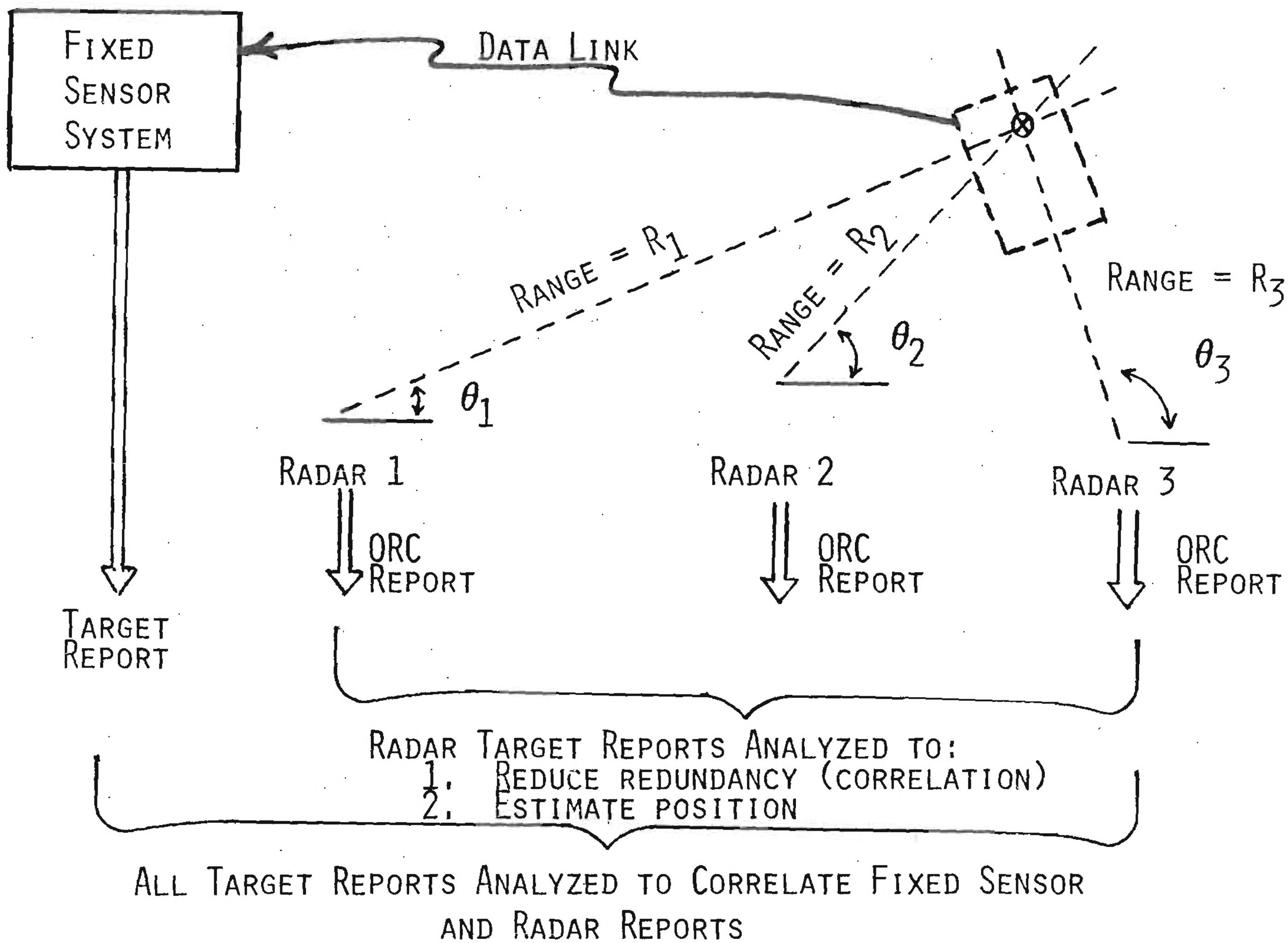


Figure 5. Sensor alarm processing priority.

algorithms to reduce the errors in estimating intruder position. After the ORC reports have been processed, all sensor reports are analyzed to correlate fixed sensor alarms with the radar track data.

2.3.6 TRACK GENERATION

The first step in track generation is to correlate ORC reports having a high probability of belonging to the same potential target. This correlation process is accomplished by the ORC association algorithms that are used to examine the incoming data in a real-time mode and to flag the reports possibly generated from a common source. For several reasons, a unique approach to the association problem has been taken with the netting of personnel detecting radars. Conventional methods of target association that are used with scanning radars to track aircraft commonly use past track data to project a search area (or volume) for the next scan of the antenna. This works well for cases where the target has finite momentum relative to the scan speed of the radar (i.e., the target will continue moving at about the same speed with only a predictable change in speed or direction). These tracking principles can not be used with personnel detecting radars to automatically monitor the track of a walking man on a track-while-scan basis since the human target can effectively change speed and direction between steps (a time interval that will be small compared to the time between scans).

This momentumless model of a human target requires that the ORC association algorithms be applied in the reverse order to that in which the reports were made. Each ORC report is compared to recent ORC reports to determine if a match can be made with any recent reports or tracks (a group of previously associated ORC reports meeting the track initialization criteria). ORC association in the netted personnel detecting radar system also must be made with little or no information on the size, speed, or direction of the motion of the target. Some radar signal processors are capable of measuring the radial velocity of the target with respect to the radar, but this information is of little use unless the direction of the target is known at the instant corresponding to the radial velocity measurement.

ORC association can be accomplished for the netted personnel detection radar application through the use of a zero order filter having a search zone based on a preselected maximum velocity. The association process compares each ORC report as it is received at the netting computer to determine if any recent ORC reports lie within a preset association circle about the ORC being tested. The size of the association circle is determined by the time difference between the two ORC reports being compared and the maximum velocity estimate established for the targets. The size of the association search circle may be different for each ORC pair processed by the association algorithms since the time between reports will vary. If a possible match is made with more than one ORC report in the computer file, then the association will be made with the one that is closest to the ORC report under test. These basic ORC association algorithms were developed and field tested during the LARIAT system feasibility demonstration (see Appendix A).

The association algorithm will depend upon a circular buffer storage table contained in the netting computer. The concept of this circulating ORC association table is illustrated in Figure 6. The table allows for temporary storage of several parameters for each ORC report. The total number of reports that can be accommodated will be determined by the amount of memory space allotted for this purpose. The size of this memory is a trade-off between computer resources and the minimum time that the track information must be stored in this short term memory (magnetic disk or tape may be used for long term storage of ORC reports and associations). The following example illustrates several considerations that impact on the computer memory space required for the circular ORC association buffer. If we assume a maximum limit of 20 target tracks at any instant with each track being simultaneously scanned at an average rate of 10 seconds per scan by at least two radars (overlapping coverage implied), a total of 4 ORC reports will be generated each second. If the minimum time that ORC information is to be retained is 10 minutes, then an ORC buffer file of at least 2000 reports must be maintained for this period. Each ORC report will contain a minimum of 5 words. These will include the X and Y coordinates, the time of the ORC report, the time flag of any previous ORC report that is associated, and a track identification (ID) number (when the associated ORC reports meet the requirements established by the track initiation algorithms). These items would require a total of five words per ORC report making it necessary to reserve a total of 10,000 words in the ORC buffer to meet the minimum storage time for the assumed 20 target tracks.

A simple example of the ORC association table is shown in Table 3. This example is limited to the movement of a single target for simplicity in the explanation. The ORC reports are received in near real time along with a time flag giving the time of detection. The reports are entered into the ORC buffer storage in the order that they were detected, but may appear in slightly different order if multiple radars are being used (depending on the multiplexing/communication format for receiving information

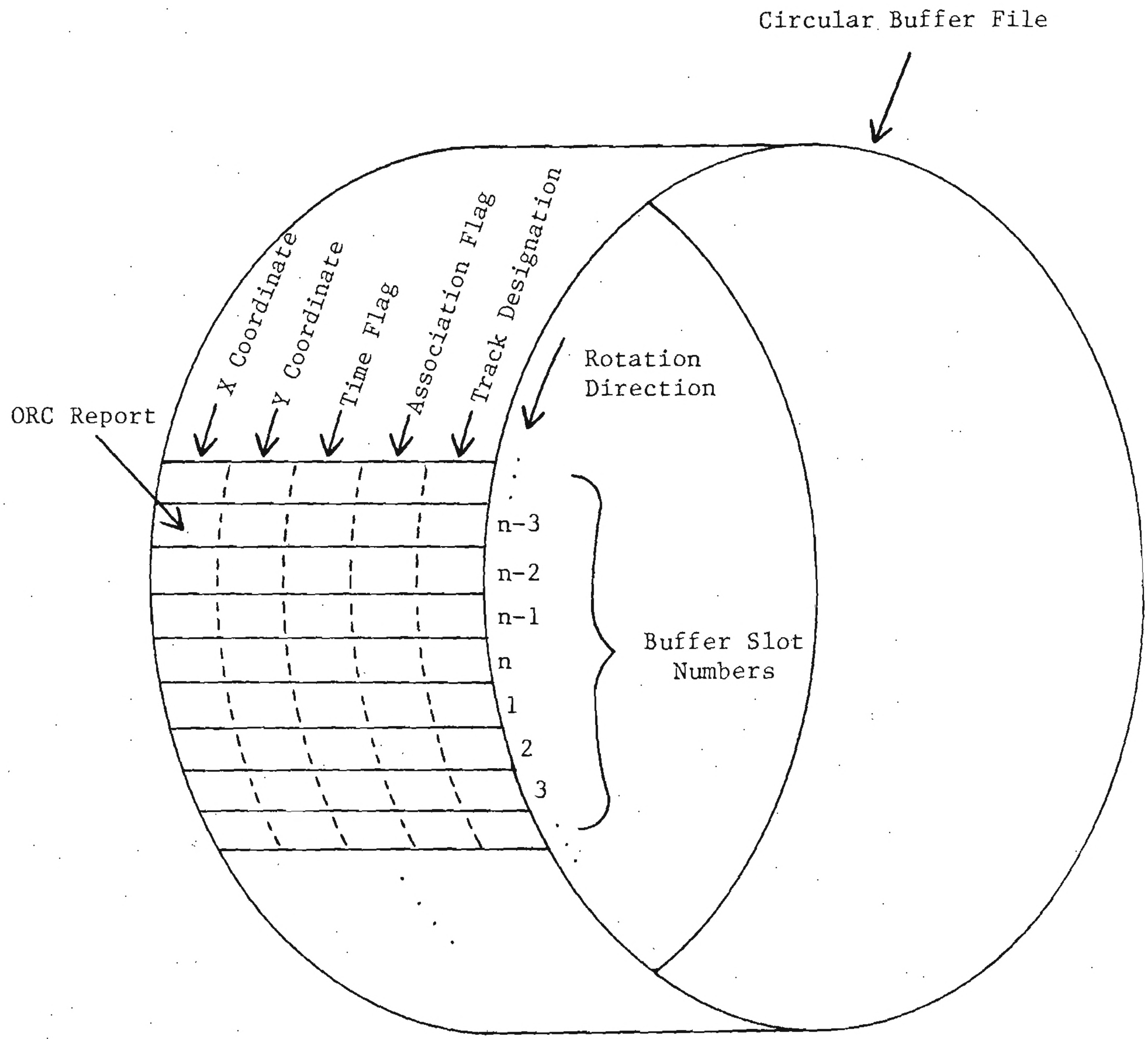


Figure 6. Recirculating ORC table.

TABLE 3. NETTED RADAR SENSORS ORC ASSOCIATION TABLE.

X-Position	Y-Position	Time	ORC Association
X_1	Y_1	T_1	-
X_2	Y_2	T_2	T_1
X_3	Y_3	T_3	T_2
X_4	Y_4	T_4	T_3
X_5	Y_5	T_5	T_4
X_6	Y_6	T_6	T_5
X_7	Y_7	T_7	T_6
X_8	Y_8	T_8	T_7
X_9	Y_9	T_9	T_8

Association given by time flag of linked ORC

Association search made in reverse time order from the remote radars). The association search is made in the reverse time order as shown by the arrow between T-9 and T-8. When an association between two ORC reports is made, then the time of the associated ORC report is inserted into the ORC report being tested (as illustrated in the ORC association column of Table 3). This ORC association pointer allows the track history to be easily reconstructed as needed. An ORC association table generated from a multiple target track situation will contain interleaved ORC reports, and the different tracks can be resolved into individual tracks by following the appropriate track pointers.

The drawing in Figure 7 illustrates the ORC association process for the single target example described above. The circular search zone is shown around the T-9 ORC report with a diameter that is determined by the time difference between the T-9 report and the T-8 report. Since the T-8 report falls within this search zone, an association is made and the T-8 time pointer is entered in the T-9 ORC report as described above. This figure illustrates that the points are not required to lie on a straight line or to follow a straight track for the ORC association algorithms to work.

The simple example discussed above illustrates the string of associated ORC reports relative to a track path. When a track is generated in the computer using the string of ORC associations, it will be in the form of an estimated track that is fitted to the X-Y coordinates of the ORC reports. This fitting process will produce a filtered track giving (1) a predicted position and (2) a predicted velocity (speed and direction) of the actual target. This concept is further illustrated in Figure 8 where the string of associated ORC reports are represented by a dashed line. The ORC locations are shown to be staggered about the actual target track since this is the effect that is produced by the limited range and azimuth resolution of the radar sets. Notice that the spacing interval between adjacent ORC reports may not be constant. This effect is produced by random scan times when multiple radars detect the same target or a sector scan when the target is not in the center of the sector. The estimated position of the target (represented by the arrow head of the filtered track in Figure 8) is seen to lag the actual position of the target track (represented by the arrow head of the target track vector) since the radar data are available only when one of the radar sensors is scanning the actual target track. In practice, there will also be some lag in the output of the filtered track data when compared to the ORC report associations due to the computational demands of the track filter algorithms.

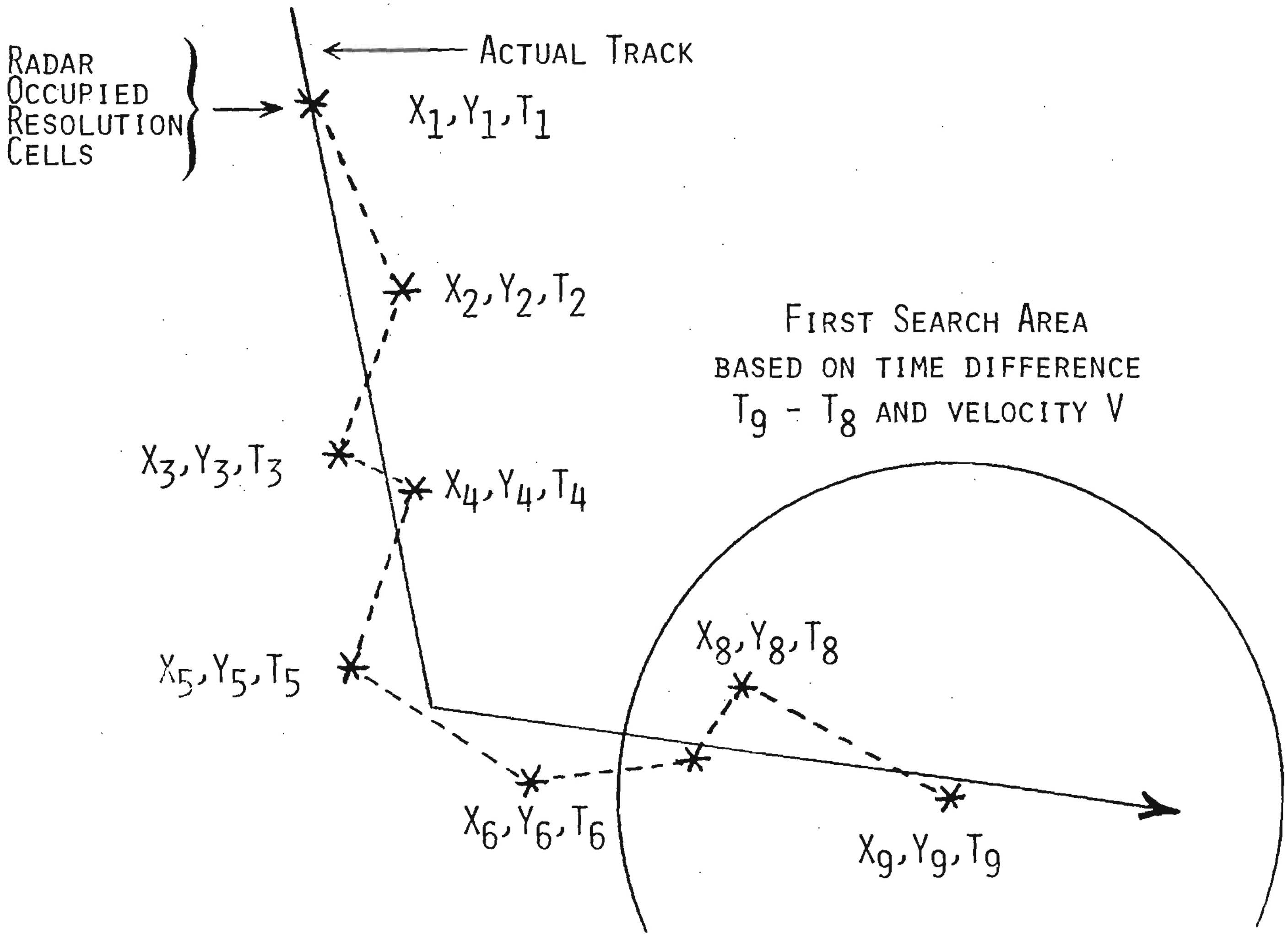
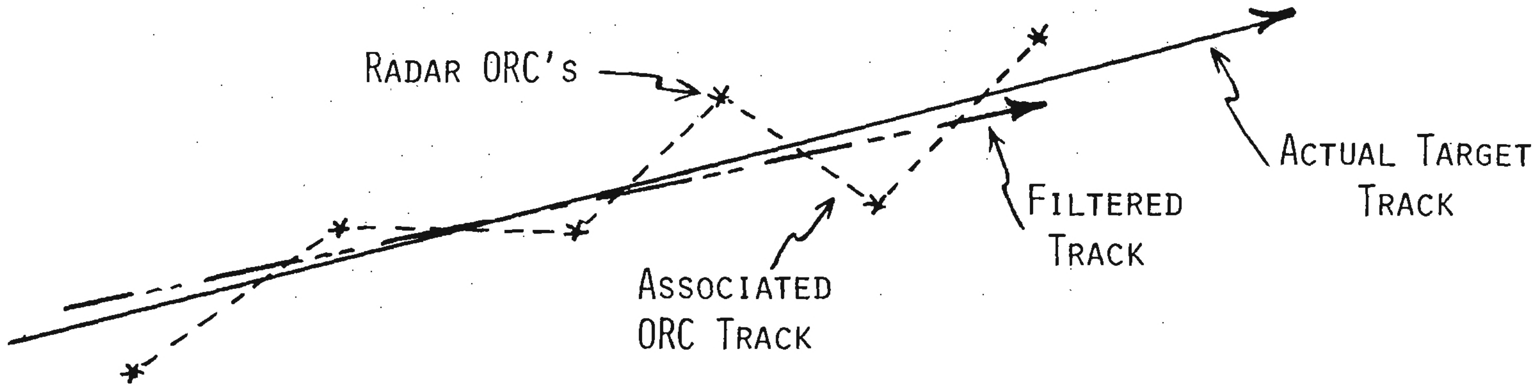


Figure 7. Netted radar sensors ORC association.



TRACK FILTERS ARE USED TO

1. PREDICT POSITION AND VELOCITY OF TARGET
2. AVERAGE POSITION ERRORS DUE TO LIMITED RADAR RESOLUTION

Figure 8. Netted radar sensors computer track generation.

2.3.7 RADAR SIGNAL PROCESSING

2.3.7.1 General Hierarchy

The radar signal processing concepts include a number of algorithms that will be applied to the radar data in real time at the radar preprocessor (located at the remote radar site). A simplified block diagram of the signal processing hierarchy for the three types of radars is given in Figure 9. The three basic divisions of the netted radar system are illustrated here by the horizontal dashed lines dividing the system into the remote radar site equipment, the data link section, and the central facility that includes the netting computer and the operator/display functions. Additional radar inputs will be represented in the system by parallel inputs to the association algorithms block. A moving target processor is assumed to be included in all the radars to provide the needed target to clutter separation.

The next block in the chain from the area surveillance radar is the CFAR algorithms. This functions as a variable threshold detector with the threshold value being adjusted by the activity in the range cells immediately adjacent to the cell being evaluated. In a pulsed radar system (typical of the AN/PPS-5 system assumed in the security system scenario), this can take the form of simple amplitude averaging of the contents of a number of cells adjacent to the cell being tested. This process is repeated for all range bins at each antenna azimuth (or several times while the target is within the beamwidth of the scanning antenna). Range-azimuth cells that have target signals above the CFAR threshold will be declared as occupied resolution cells (ORCs) and the ORC generator will initiate an ORC report (here in polar coordinates). The CFAR algorithms may take alternate forms particularly for the short range sector radars that typically transmit a modulated FM carrier. These alternate CFAR systems for the FM radars will have similar algorithms making the ORC rate dependent upon the activity in the adjacent resolution cells.

The next function in the signal processing chain for the area surveillance radar is the R-Theta blanking. This function is seldom required, but is a principal tool for eliminating interference from adjacent radars. The algorithm allows for sectors or pie sectioned wedges where all ORC reports are ignored to be defined in polar coordinates. At this point, all ORC reports are converted to Cartesian coordinates. A similar blanking function is applied as a filter to the ORC reports in the X-Y coordinates. This second blanking function is necessary to eliminate areas previously identified from maps as being of little or no interest to the surveillance problem. The sections to be blanked may be dictated by the border of the security surveillance area.

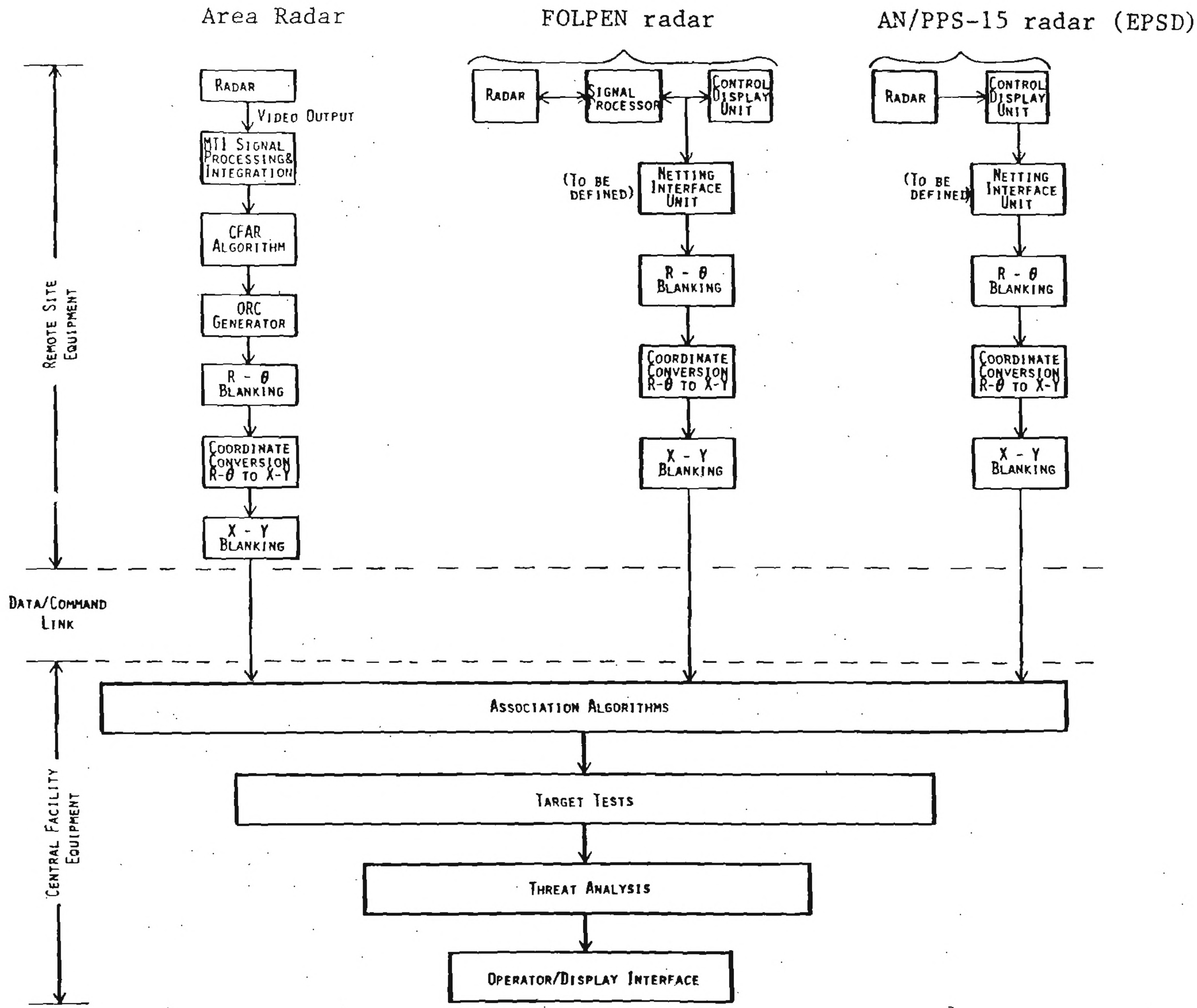


Figure 9. Radar netting signal processing hierarchy.

The sector surveillance radars are shown to have a netting interface unit in Figure 9 that is labeled "to be defined." This functional box will include the ORC generator along with any CFAR or integrator algorithms. This section of the signal processing is left undefined at this point since there is ongoing development activity in this area for the two sector surveillance radars being considered in this netting study. The provisions for blanking in polar coordinates is recommended for the sector surveillance radars. A provision for X-Y blanking is also recommended.

The principal algorithms in the netting computer are the ORC association algorithms. For a maximum capacity netted system having a high degree of overlapping radar coverage, these algorithms provide a degree of data reduction and form the basis for the automatic detection that is desired to reduce the operator load.

2.3.7.2 Target Test - Threat Analysis

Several tests of each associated ORC string will be made within the netting computer. The first tests will be to determine if an ORC string meets the requirements necessary to be declared a target track. This criteria has been previously defined as a preset number of hits within a given time period (or within a given number of possible scan events). When this threshold is met, a track flag is associated with the ORC reports in the netting computer and other track algorithms are initiated. Target threat assessment and alarms will only be made on declared tracks. This definition was made earlier, but the importance may only be seen after understanding the ORC association process. The data used for threat assessment and alarming are greatly reduced from that generated at the output of the radars. The basic tools for analyzing the target track data are the track filters and the scenario map giving predefined warning boundaries. This simple approach is used to provide some degree of automatic analysis of the radar information without requiring the development of new capabilities in the radar systems. The simple threat analysis criteria described here operated satisfactorily in the LARIAT field test against actual threat targets. Discussions of additional threat analysis tools are included in later sections of this report.

Two alarm levels have been proposed for the netted security system. A Yellow Alert has been defined for any declared target track that is within the base boundary (as stored in the netting computer). This alarm is used to call the system operator's attention to the condition that a new target is being tracked by the system. The operator can interact with the system at this point to request additional information on the target track or to enter track information to be associated with the track if he possesses such knowledge. In the case of split tracks or merged tracks, this information may be obvious to the operator from the scenario map display. The identity of a track may also be known from other sources such as remote observers, remote TV-optical systems, or radio contact with the target.

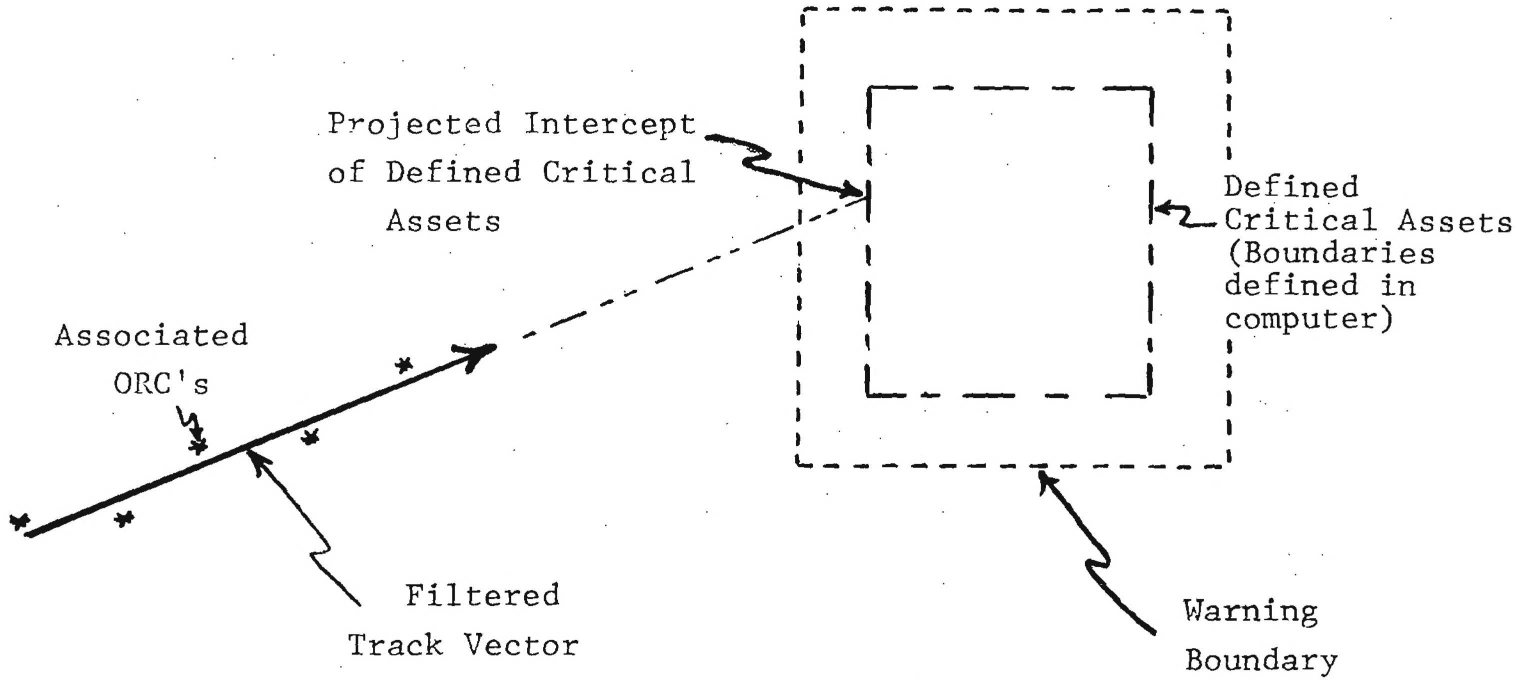
Crossing tracks are handled by the same track algorithms. Two tracks that cross will still be maintained as two separate tracks, but no guarantee can be made that the same identity of the tracks will be correct after they cross. This is not considered to be a severe limitation on the netted surveillance system since all intruders will be automatically tracked.

The yellow alert is also proposed for use with reports from general purpose fixed sensors. The philosophy here is that a disturbance from a single fixed sensor is an unconfirmed intrusion report that requires the attention of the system operator, but does not demand immediate action.

A Red Alert is proposed for conditions requiring immediate action from the system operator. A red alert will always be used for (1) any target track within a defined critical asset area, (2) any target track projected to enter a defined critical asset area, or (3) any target track of radar ORC data that is correlated with a fixed sensor alarm. The defined critical asset area is a predefined boundary (within the prescribed base area) that is set aside as requiring immediate action when an intruder alarm is received. This critical asset area may be reserved for such items as weapon storage, communication facilities, power distribution facilities, or remote radar surveillance sensors.

Provisions for a conditional Red Alert will also be made for defined high priority fixed sensors. This will hold for unconfirmed alarms when the location of the fixed sensor is protecting an area or device that demands immediate response.

The concept of alerting on tracks that are projected to enter a critical asset area is illustrated in Figure 10. The inner rectangle is the defined critical asset area, and the outer rectangle is the warning boundary that is used to initiate the track projection algorithms that test for possible intersection of track and the inner rectangle. All track projections are made from the filtered track vector. A Red Alert is issued when both of the following conditions are met: (1) a target track intersects or exists within the outer perimeter boundary and (2) the projected track intersects the defined critical boundary.



"Red" Alert occurs when all three of the following conditions exist:

1. A target track exists within the outer perimeter boundary
2. The target track intersects the <u>warning boundary</u> around the Defined Critical Assets
3. The projected track intersects the Defined Critical Boundary

Figure 10. Netted radar sensors "red" alert.

2.3.7.3 Operator Target Assessment Options

Several possible options are available to assist the operator in determining the identity of a possible target. When an alert is made to the operator, several conditions have been met to ensure with high probability that the disturbance is a real target. The proposed algorithms have not defined a capability for eliminating responses due to unwanted real targets such as large animals. One criteria proposed (but not sufficiently tested during the LARIAT feasibility demonstration) is the use of the output of the track filters to measure the randomness of the speed and direction of the target track to separate feeding animals from targets moving with a purpose as though trying to reach a known destination. While this is a simple test to include in the target testing algorithms, it could be very useful in base areas where cattle graze in the open or large game (such as deer) exist in significant numbers.

The first and most straightforward method for verifying the identity of a target is to send out a patrol. This can be very costly over a long projected system operating period of several years. Patrol response capability can also be easily saturated when a large number of tracks appear on the scenario map display. In some cases, the system operator can be helped greatly by the use of remote TV surveillance systems. These devices can be either fixed area surveillance units (such as monitoring the area around buildings or approach paths) or a remotely controlled system capable of changing the pointing direction, the pointing elevation, and the magnification. Automatic pointing of the remote TV sensors can easily be included within the netting compter and would require only that the system operator designate the track on the display and request TV verification. A TV target verification system can coexist on the same tower with the area surveillance radar. This addition can greatly reduce the number of security patrol responses necessary and can even operate in the dark with the use of low-light TV cameras. Other useful optical sensors are available to augment the TV target verification option.

A very simple target assessment option already exists in some of the netted fixed sensor systems in the form of an acoustical microphone. This device can be activated to allow the operator to listen to sounds that may be generated by targets in the vicinity of the microphone. This technique is most effective when fixed sensors are deployed along a track that indicates an intruder plans to enter a critical asset area (i.e., an area also including fixed sensors).

Radar Doppler analysis is a very powerful method for identifying a target from the reflected radar signal. The movement of the target produces return reflections that are changed in frequency from those transmitted by the radar. This is the principle that makes possible the detection of small moving targets in the presence of large levels of ground clutter through MTI signal processing. It has long been known that a trained operator could identify many targets by listening to the Doppler return from a radar set while the antenna remains pointed at the target in a "search light" mode.

The ability to acoustically monitor Doppler returns is currently instrumented in the AN/PPS-15 and AN/PPS-5 radars. The simplest method of using this target assessment tool is to provide the operator with a means of taking one of the radars out of the track-while-scan mode and to manually locate (via remote control) the Doppler range cell over the target. This concept was instrumented in the LARIAT system design but proved to require a longer than desired time to acquire the target within the Doppler range bin. A more interesting option would be to partially automate the process of positioning the Doppler range bin over the target. In this semiautomatic system, the operator would designate the position on the scenario map and the appropriate radar would automatically slew to the proper azimuth and adjust the Doppler range bin to the correct range. In either the manual or semiautomatic approach, an indication of the sampling bin position must appear on the scenario map. Either of these methods for Doppler monitoring of the target return provides a good analysis tool that is readily within the state of the art of both the radar sensors and the computer/software required for the netting computer.

A very desirable capability for the netted surveillance system would be a completely automatic Doppler analysis of the radar return from targets. At present, this capability is not readily available, but with current target identification technology it is possible to develop the necessary algorithms for this function in the near future. Since this would improve the efficiency of the overall surveillance system, provisions should be included for this capability to allow this feature to be added at a later date.

2.3.7.4 Radar Sensor Security

A netted security system depending upon the remote operation of radar sensors should provide for detecting and alarming on possible conditions of (1) someone tampering with the equipment, (2) someone approaching the radar site, or (3) the presence of electronic tampering in the form of radar jamming countermeasures. Door switches can easily indicate when a unit is entered. An acoustic sensor with a high threshold setting can also be used to detect impacts of small arms fire which may indicate intruder activity and possible damage to the radar. The small sector radar mounted on a tripod can be easily moved or pointed in a different direction. If the pointing direction of such a radar sensor was changed (by either friendly or unfriendly forces) without knowledge of the system operator, the operation of the netted surveillance system could be greatly impaired. For this reason, it is proposed that simple tilt and vibration sensors be included in this class of radars.

In some applications, it may be desirable to include a capability for detecting personnel approaching the remote radar site. The capability would be in addition to that provided by the netted system through the use of defined critical asset areas. Short range proximity sensors such as leaky coax are available for this application. The output of the proximity detector would be interfaced to the radar set, and alarming conditions would be transmitted with the radar sensor security status reports.

Electronic countermeasures can be a definite indication of attempts to cover an intrusion into the defended base area. From this standpoint, this event should be immediately passed on to the system operator so that appropriate action can be taken to determine the source of the interference and to possibly adjust the tactics for responding to detected targets.

These detector/alarm functions are considered necessary for proper operation of a netted security system. While all of the functions may not be required for every type of radar sensor, for future expansion it is proposed that the capability be provided at this time since the two types of sector radars being considered in this study are either under development or are being considered for a product improvement program. A list of the proposed communication requirements and the corresponding sensor capabilities is given in Table 4. The actual mix of the sensors listed in this table may change from radar to radar.

2.3.7.5 IFF Beacon Transponder Option

One option that is possible for target track identification is the use of a beacon transponder system to identify as friendly troops target tracks that are generated by security patrols or maintenance crews. This concept option can provide automatic location and track information of the friendly forces on the situation display map. This capability will also provide a unique tool to assist in survey of the surveillance site (a problem in quick deployment applications) by returning a measure of the range and azimuth to the transponder interrogator.

The IFF transponder system can be designed to operate through one of the radar systems, or it can be designed to be an independent facility. An IFF system was included

TABLE 4. SECURITY FOR REMOTE RADARS.

- o Equipment Tampering Sensors (8 Sensors Maximum - 3 Bits)
  - o Door Switch - Detect Entry of Equipment
  - o Vibration - Detect Gross Movement of Equipment
  - o Acoustic - Detect Impact of Small Arms Fire
  - o Smoke - Internal Fire Sensor
  - o Temperture - Internal Fire Sensor
- o Personnel Detectors (1 Bit)
  - o Short Range Proximity Sensors
- o Electronic Tampering/Jamming-Countermeasures (2 Bits)
  - o Electronic Monitoring of Radar Receiver

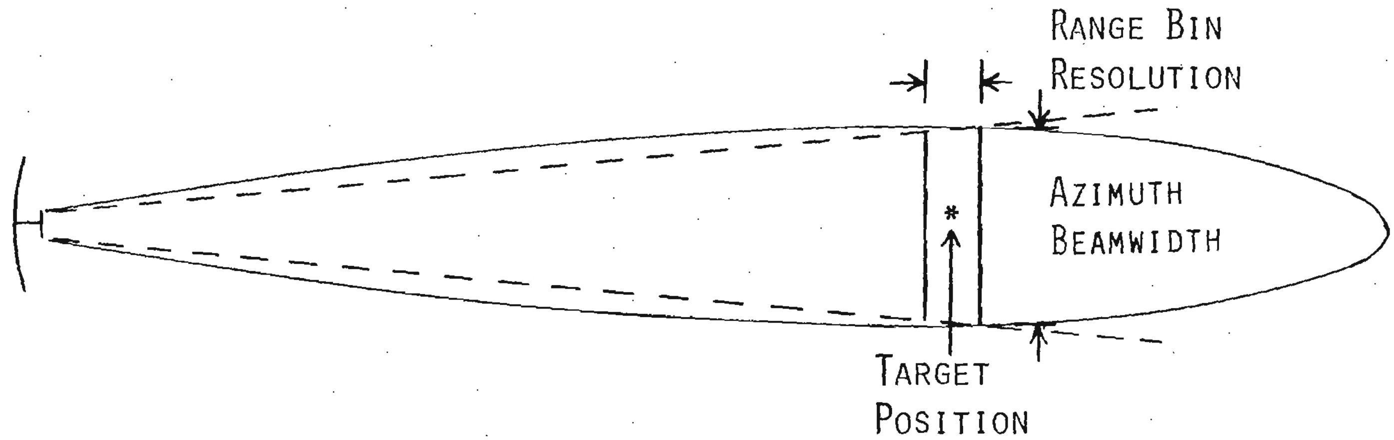
    (Receiver Noise and/or Isolated Resolution Cell) in the feasibility test of the LARIAT system and proved to be a very useful addition to the surveillance system. In this experiment, the IFF system responded through either of the two AN/PPS-5 area surveillance radars and the system had a capability of using up to 8 IFF transponders. The LARIAT system was tested with three transponders having a range reporting resolution of 6.25 meters.

2.3.7.6 Radar Location Accuracy

The three radar systems considered in this study have been described as having a finite range resolution as listed previously in Table 2. This basic limitation is controlled by such radar design parameters as pulse width (for the pulse modulated system). Azimuth resolution is determined by the antenna beamwidth and is also dependent upon target distance from the radar. These two location resolution concepts are illustrated in Figure 11. With these basic resolution limits, the location accuracy of a target is limited to one-half of the range bin resolution and to one-half of the beamwidth (assuming that no further processing has been performed and that the absolute accuracy of the system is equal to or greater than the location resolution). Processing algorithms exist for improving the location estimation resolution by averaging the target response in the adjacent resolution cells to predict the actual location of the target. The algorithm for increasing the range resolution is called range bin splitting. Azimuth resolution is increased by the beam splitting algorithm. These algorithms work only when there is one target within the resolution cell and the immediately adjacent cells are empty. When multiple targets are clustered in the same resolution cell, these algorithms typically predict the centroid of the target group.

The limitations in the target location accuracy impacts on the data link specifications and the netting computer. The three radars considered in this concept study are representative of current technology and units that may be produced in the near future. The performance of these radar systems will be used to generate the recommended communication requirements for the data link and command links for the netted radar-fixed sensor surveillance system. A summary of the location accuracies of these three radar units appears in Table 5. The accuracy is a function of the range to the target as discussed above.

The recognized limits on location accuracy of the radar sensors leads to a conclusion that the nominal location resolution will vary between 10 and 50 meters. In defining the requirements for a netted radar-fixed sensor surveillance system, the following requirements were assumed: (1) the maximum location resolution to be



RANGE ACCURACY: ±½ RANGE BIN RESOLUTION

AZIMUTH ACCURACY: ±1/2 (RANGE) (BEAMWIDTH)
(WITHOUT BEAM SPLITTING)

Figure 11. Radar location accuracy.

TABLE 5. TYPICAL RADAR LOCATION ACCURACIES.

RADAR	TARGET RANGE	RANGE LOCATION ACCURACY	AZIMUTH LOCATION ACCURACY
AN/PPS-5(M)	0.5 KM	± 50 METERS	± 3 METERS**
	1.5 KM		± 9 METERS
	3.0 KM		± 18 METERS
	10 KM		± 60 METERS
FOLPEN	0.5 KM	± 30 METERS	± 90 METERS
	1.5 KM		± 270 METERS
	*	—	—
	*	—	—
AN/PPS-15	0.5 KM	± 40 METERS	10 METERS***
	1.5 KM		30 METERS
	3.0 KM		60 METERS
	*	—	—

* EXCEEDS MAXIMUM INSTRUMENTED RANGE

** BASED ON NO BEAM SPLITTING

*** BASED ON OPERATIONAL DATA

transmitted will be 10 meters, (2) the maximum reporting radius of any radar will be 10 kilometers - the maximum instrumented range of the area surveillance radar sets, and (3) all ORC reports will be made in Cartesian coordinates. These assumptions will allow the ORC position reports to be defined with a minimum of 11 bits for the X-coordinate and 11 bits for the Y-coordinate.

The time flag in the ORC report is the key to the ORC association algorithm. It is also desirable to retain the ability of tracing target activity that may have been recorded on a magnetic tape log for later analysis. For these purposes, a time resolution of 1 second in a period of 24 hours is recommended. This resolution can be accommodated in a 17 bit binary code.

2.3.7.7 Interface and Communications

The netting computer is the principal nodal point of the netted radar-fixed sensor security system concept. A great deal of emphasis was placed on the description of the data-link and command link interface between the netting computer and the remote radar sensor systems. While the operator-display unit might not be operated remotely from this unit, a general definition of the interface requirements and the communication format is equally important in the design of the netted surveillance system. The design concepts used in this section of the netted surveillance system must not limit the use of the operator-display unit at a remote location or the use of parallel remote status display units.

The design of the interface to the operator-display unit must accommodate all target messages generated in the netting computer including: (1) target-track locations, (2) target alarms, (3) IFF location/information, and (4) target assessment information. Several other types of messages must also be transmitted to the operator-display unit (see Table 6) during the normal operation of the netted surveillance system. A header message preceding each transmission from the netting computer will be used to define the message category that follows. This procedure will allow a priority interrupt system to be used within the operator-display unit to service the interface items of highest priority first. The design philosophy assumed in this general interface discussion requires that the operator-display unit have a memory capacity sufficient for maintaining the short term target track and alarm information required for the situation map display to the operator.

Long term recording equipment used to record target activity (such as digital tape) can be located with either the netting computer or the operator-display unit. With

TABLE 6. MESSAGES TO OPERATOR-DISPLAY UNIT

- Five Types of Messages will be Transmitted to the Operator-Display Unit

  - Header Message - This Message is Transmitted for All Communications to the Operator-Display Unit - Presents an OK Status or Defines the Failure Message to Follow

  - Failure Message - Always Preceded by a Header Message - Gives Basic Target or ORC Information from Radars and Fixed Sensors

  - Sensor Report Message - Always Preceded by a Header Message - Gives Basic Target or ORC Information from Radars and Fixed Sensors

  - IFF Report Message - Always Preceded by a Header Message - Transmitts IFF Transponder Information on Friendly Tracks

  - Tamper Reports - Always Preceded by a Header Message - Transmits Information on Tampering With Sensors, Interference or Jamming of Radars, etc.

this design approach, the netting computer will pass target and status reports to the operator-display unit as they occur and will not maintain a target file for further recall by the display facility.

The netting computer must also respond to communications generated within the operator-display unit. These communications must accommodate the basic messages for (1) system initialization, (2) control of the operating parameters of the radar units, and (3) initiating the self-test functions of the system. Other message formats will be allowed, depending upon the options included within the netted security system design. One option discussed previously is the ability to remotely control a sampling gate in the area surveillance radars for Doppler analysis of the radar return from moving targets. The controls for this function will be accommodated in the command message format controlling the radar operating parameters. The IFF option described earlier can operate automatically and does not require any special commands from the operator.

The resolution and bit rate required in the interface data-links between the netting computer and the remotely operated radar units were defined in considerable detail. The interface to the operator-display unit was also defined. A partial list of information proposed for the target report is given in Table 7. The position reporting information maintains the same 11 bit resolution for each coordinate. The target velocity information derived within the netting computer should be reported as one of seven velocity classes.

This information will be a product of the track filters and does not represent measurements made on the Doppler return of the individual radar signals. The computer derived target speed will be an averaged estimate based primarily on the time-location differences between consecutive ORC reports and will be subject to the resolution limitations of the radar locating systems. Therefore, the seven velocity classes will allow the relative target speed to be conveyed to the surveillance system operator.

A resolution for target direction of 5 degrees has been proposed for reporting of this target analysis algorithm since this is compatiable with the plotting accuracy of the display system. This information is intended only to indicate the relative direction of the target movement to the operator. The basic time resolution of one second within a 24 hour day will be preserved in the target message to the operator-display unit. In this netted surveillance system scenario study, a capability of reporting up to 320 individual fixed location sensors is accommodated. This number is not a hard limit, but represents a realistic benchmark for this concept study.

TABLE 7. PROPOSED TARGET REPORT DEFINITIONS

o Target Speed - Proposed that Velocity Classes be Reported as Follows:

Velocity Clear	Target Speed
1	0 - 2 km/hr
2	2 - 4 km/hr
3	4 - 8 km/hr
4	8 - 20 km/hr
5	20 - 40 km/hr
6	Over 40 km/hr

SECTION 3
PROPOSED SYSTEM CONCEPT

Many system netting concepts presented in the previous sections of this report were previously tested in feasibility demonstrations of the LARIAT netted radar system. The extensions of the initial netted radar surveillance system concept to include an active interface connection to a large group of fixed-location security sensors is a natural development in the design philosophy for centralizing the surveillance information available to the system operator. This extension in the netting concept can be accomplished with current state-of-the-art hardware and with low development risk. The radar system requirements are based on moving target indication (MTI) signal processing techniques equivalent to that used in battlefield applications of similar radar surveillance equipment.

This proposed concept design will reference much of the material already presented in this report. The concept design discussed here represents a benchmark based on the assumed system scenario defined previously in Table 1. The proposed system design must accommodate the full scenario system requirements and be adaptable to applications where reduced radar surveillance is required. Two design levels to accomplish these goals were considered. The goals of this concept design are listed in Table 8 based on a two-level system design approach.

A full capability system is defined as one that is based on the requirement of wide area radar surveillance and includes the fully automated target processing capabilities presented in the netting concept discussions. Security-surveillance systems having only limited radar search requirements are provided for in a reduced capability system. The reduced capability system is directed toward applications including one or more radar units (primarily of the short-range sector-scanning variety) with a netting configuration of fixed location sensors.

The design concepts and the proposed netted surveillance system configuration presented in this report will not limit the use of the netted sensor system in an all radar configuration or an all fixed location sensor configuration. The concepts presented here are usable in any mix of radars and sensor units, and the maximum number of sensors used in this benchmark design is based on the assumed system requirement scenario.

A major key to the netted surveillance system design is the degree of automation for target processing and threat assessment that is included. The reduced capability

TABLE 8. DESIGN PHILOSOPHY

- Two Levels of a Netted Radar/Fixed Sensor Surveillance System Will be Examined to Address:

  1. A Full Capability System based on wide area radar surveillance and on the fully automated target processing capabilities presented in the concepts discussions. This concept design will be capable of netting a maximum of 8 radars (including up to two area radars).

  2. A Reduced Capability System providing a minimum of automated target processing and depending upon the system operator to perform some of the operations of target correlation and assessment on the system display. This concept design will be capable of netting a maximum of 8 radars, but is primarily intended for use with the short range sector radars with limited overlapping coverage.

- The netting conepts considered here should not limit the use of the netted sensor system with an all radar configuration or with an all fixed sensor configuration.

- The maximum number of radars (8) is an arbitary limit assumed in the senario.

system will not be as well developed in the area of automatic processing of sensor data and will depend upon the system operator to perform some of the operations of target correlation and assessment with the aid of the system scenario map display. The full capability system will include algorithms for the automatic detection, tracking, analysis, and alarming on intrusion reports from the radars and the fixed sensor units contained in the netted system. Table 9 defines the target processing algorithms for the two proposed levels of system design. These data processing capabilities have been defined in the previous discussions on netted sensor surveillance systems. This table clearly identifies the signal processing algorithms that are not automated in the reduced capability system. The IFF function was described as an option for the full capability system.

A more detailed summary of the signal processing algorithms for the radar and fixed location sensor data reports is given in Table 10. The separation of the two levels of the netted system design is preserved in this listing, but the algorithm functions are grouped in a slightly different order to better identify the basic functions of target detection and track analysis. The first algorithm group contains six functions that form the automatic target detection and track generation algorithms that are contained in the netting computer. These target processing functions exist in both the full capability system design and the reduced capacity system. The hardware requirements for the two applications may differ somewhat in memory requirements and data processing speed. This is due primarily to the differing amounts of sensor data that must be accommodated. The basic signal processing algorithms and the hardware design for the reduced capability system can in principle be expanded to accommodate the full capability system design.

The basic principle for achieving the high degree of automatic signal processing for the high data rate encountered with the radar sensor units is through the development of efficient signal processing algorithms and the use of a distributed signal processing concept. By extending portions of the signal processing facilities to the radar sites, the redundancy in the radar signal output can be used to significantly reduce the data rate requirements. The algorithms for target detection are also designed to greatly reduce target reports generated by spurious radar responses to system noise and natural phenomena. The preferred location of the target processing algorithms in the netted system is given in Table 11.

A general block diagram of the netted radar-fixed sensor surveillance system is given in Figure 12. This block diagram includes all elements of the full capability system concept including an interface to both the FIDS and the SPCDS systems (see Appendix A

TABLE 9. NETTED RADAR-FIXED POINT SECURITY SYSTEM CONCEPT CAPABILITIES

	Function	Full Capability System (FCS)	Reduced Capability System (RCS)
1.	Target Detection	Yes - Automatic	Yes - Automatic
2.	Track Generation	Yes - Automatic	Yes - Automatic
3.	Radar-to-Radar Target Correlation	Yes - Automatic	Yes - Manual
4.	Radar-to-Fixed Sensor Target Correlation	Yes - Automatic	Yes - Manual
5.	Track Filters	Yes - Automatic	No
6.	Target Position Projection	Yes - Automatic	No
7.	Alarm Zones	Yes - Automatic	Yes - Automatic
8.	Threat Assessment	Yes - Automatic/Manual	No
9.	IFF Capability	Yes - Automatic (Correlation between IFF and "Skin" returns)	No

TABLE 10. NETTED SECURITY SYSTEM CONCEPT CAPABILITIES

Algorithm Function	Full Capability System (FCS)	Reduced Capability System (RCS)
1. Target Detection/Track Generation		
• ORC Association	• Time-Position Association between adjacent ORC Reports	• Same as FCS
• Track Initiation	• Based on preset number of associated ORC Reports in fixed time frame	• Same as FCS
• Track Termination	• Based on number of associated ORC Reports within fixed time frame being below threshold	• Same as FCS
• Track Split	• Established track continues along one branch and new track is generated for remaining branch	• Same as FCS
• Track Junction	• Only one established track remains with all remaining tracks terminated	• Same as FCS
• Track Crossing	• Established tracks remain but may switch targets	• Same as FCS
2. Correlation of target reports		
• Radar-to-Radar (for overlapping coverage)	• Correlation through Time-Position Association of ORC Reports	• Correlation made <u>by</u> <u>operator</u> on computer generated scenario map display
• Radar-to-Fixed Sensor	• Correlation through Time-Position Association of Fixed Sensor Data with ORC Reports	• Correlation made <u>by</u> <u>operator</u> on computer generated scenario map display
3. Track Filters/Target Position Prediction	• Algorithms for estimating direction and speed of target track - necessary for intrusion pridiction and track threat assessment	• None
4. Operator Alarms	• Warning Alarm (Yellow) based on defined track track properties (properties of speed & direction) • Immediate Reaction Alarm (Red) based on actual intrusion of predefined zone or on pridicted intrusion of predefined zone	• Simple Alarm when declared target occurs within predefined boundary
5. Threat Assessment	• Manual or Semiautomatic through operator monitoring of Doppler radar return from target (current capability) • Automatic or Semiautomatic through computer assessment of target return (projected capability)	• Manual monitoring of Doppler radar return (located at the radar)
6. IFF Capability	• Automatic correlation between IFF target tracks and tracks of "skin" returns	• None

TABLE 11. NETTED RADAR/FIXED SENSOR SYSTEM ALGORITHM LOCATIONS

Processing Requirements	Full Capability System		Reduced Capability System	
	Capability	Preferred Location	Capability	Preferred Location
Moving Target Processing/ Integration (MTI)	Yes	Radar	Yes	Radar
CFAR Algorithms	Yes	Radar	Yes	Radar
Beam Splitting Algorithms	Yes	Radar	Yes	Radar
Target Association Algorithms	Yes	Netting Computer Facility	Yes	Radar
Target Correlation Algorithms	Yes	"	———	———
Track Management Algorithms	Yes	"	Yes	Radar
Track Filters	Yes	"	None	———
Threat Assessment Algorithms	Yes	"	None	———
Operator Alarm Algorithms	Yes	"	Minimal	Netting Computer Facility

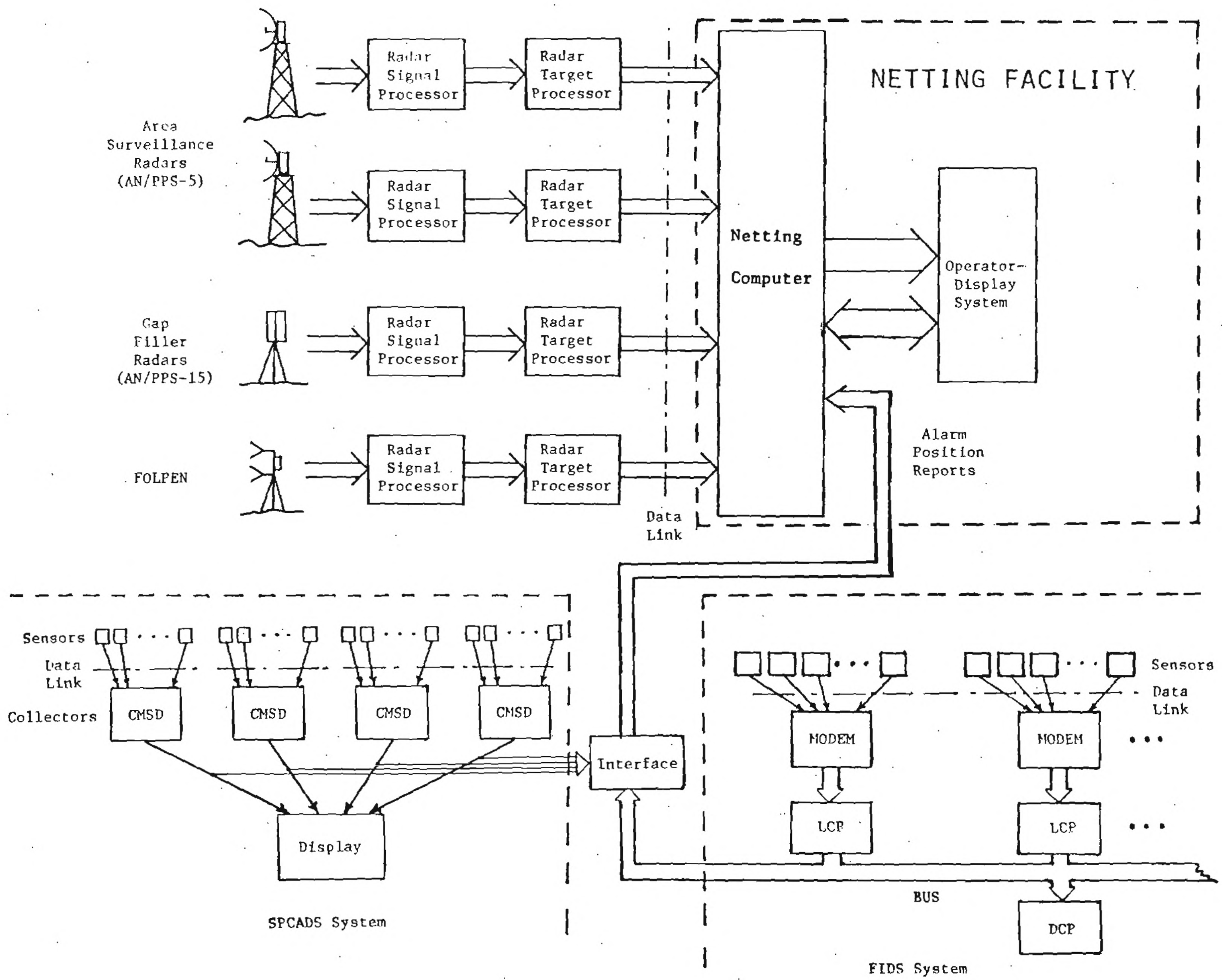


Figure 12. General Configuration of a netted radar-fixed sensor system.

for summary discussions of these systems). In reality, it is not likely that both of these fixed-sensor netted surveillance systems would be used in the same security installations, though it can conceptually be accommodated.

The nodal point of this concept design is the netting computer. This hardware and software functional block provides (1) a two-way interface to the radar units and the fixed sensor arrays, (2) the system interface to the operator-display system, and (3) the basic memory and computer facilities for performing the target detection, tracking and alarming functions. Figure 13 gives a more detailed block diagram of the automatic target handling algorithms proposed for the full capability surveillance system.

The proposed netted surveillance system design outlined in this section represents a benchmark design based on a realistic set of scenario requirements. The netting principles presented in this report are achievable with current state-of-the-art equipment and through the use of algorithms that have been demonstrated in previous investigations. The combination of these concepts and hardware capabilities can achieve a netted radar-fixed sensor surveillance system with relatively low development risk.

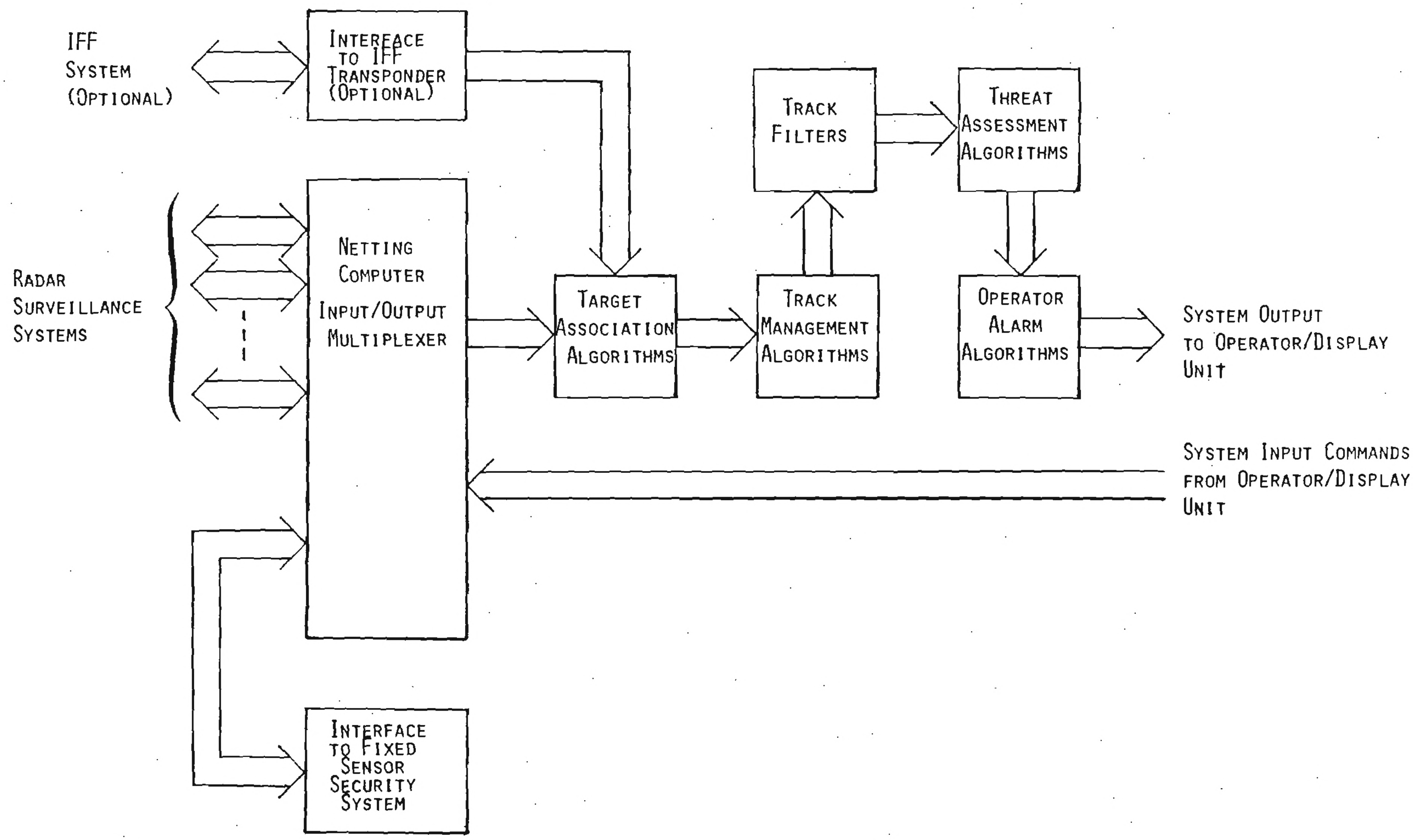


Figure 13. Netting computer for full capability system.

SECTION 4
DISPLAY CONCEPTS

4.1 DISPLAY CONFIGURATION

The display module is the operator's interface with the netted security system. The display module receives processed data from the entire system and displays that information in a graphical form that allows the operator to quickly grasp complex situations. The display module also enables the operator to communicate with the system through several types of man-to-machine interface devices.

The display module consists of three basic hardware units. The system control central processing unit (SCCPU) is basically a computer that receives messages from the netted system and generates the data to be displayed. The display unit will display the information generated by the SCCPU. The third element is the associated operator input devices and the electronics required to support their operation. Given this division of system functions, the term 'display module' is used when the entire display system is referenced, and the term 'display device' is used in reference to the unit that displays data for the operator to monitor.

4.2 PURPOSE OF THE DISPLAY MODULE

The purpose of the display module in the netted sensor system is to inform the operator of: (1) base or installation security, and (2) netted sensor system operational status. The status of total base security is displayed in graphic form using maps and symbols. In addition, messages tailored to provide specific information are presented on the display. System status in measage format is always displayed.

A second purpose of the display module is to provide amplifying information to the operator after the initial intrusion condition has been communicated. The amplifying information may include: (1) precise coordinates of the event, (2) a tailored response based on security police, (3) intruder speed, (4) past location, (5) future location, (6) security force location, and (7) other parameters. Data such as wind speed, and the presence of thunder, lightning, hail or other environmental factors (sources of false alarms) that might affect sensor operation can also be displayed using the display module concept chosen to support the netted system.

The display module would be used to record data for event analysis purposes. Parameters that would include "time of event" and "intruder track history" could be recorded, as could security force response times and associated response track histories. Each of these data would be valuable for "post event" analysis that could be conducted to improve the response tactics at a future time.

The display module can be programmed to improve operator "alertness." Human factor studies have demonstrated that workers who must be subservient to machines usually become bored much quicker than personnel who control various aspects of a system. The netted security system concept is highly automated. This is advantageous for most security situations where the operator must perform several tasks in addition to monitoring the security module display. However, when the operator's sole activity is display unit monitoring, boredom can become a negative factor. The automated nature of the netted sensor system allows features to be built into the system to test operator alertness and to require specific operator responses on a random or scheduled basis.

4.3 DISPLAY SYSTEM ARCHITECTURE

The overall netted security system architecture and communication hierarchy was discussed in previous sections. The communications scheme used to interface the display system with the rest of the netted security system, and the display system hardware and software architecture are discussed in the following sub-paragraphs.

Figure 14 is a block diagram of display module components. The netting computer shown at the left margin was described in a previous section. The netting computer processes the raw data sent by the sensors to be displayed. The netting computer communicates with the display system control CPU through a parallel data buss. Data are transmitted via this buss in a highly structured format. A reverse path is provided to allow the system control CPU to transmit device polling request and operator commands to the netted system (two-way communications buss in the primary sensor network is assumed).

The operator interface devices referenced in Figure 14 include the various devices that might be employed for man-to-machine communications. These devices may include a full ASCII keyboard, or a partial keyboard for defined functions. A joy stick, cursor ball, light pen, or touch panel may also be employed as operator interface devices. In fact, any device that allows the operator to communicate with the system would be defined as an operator interface device.

The system control CPU is a message interpreter and router. A certain amount of "scratch pad" memory is used for temporary data storage and certain algorithms are exercised in the data sorting and routing process. Thus, a section of read only memory

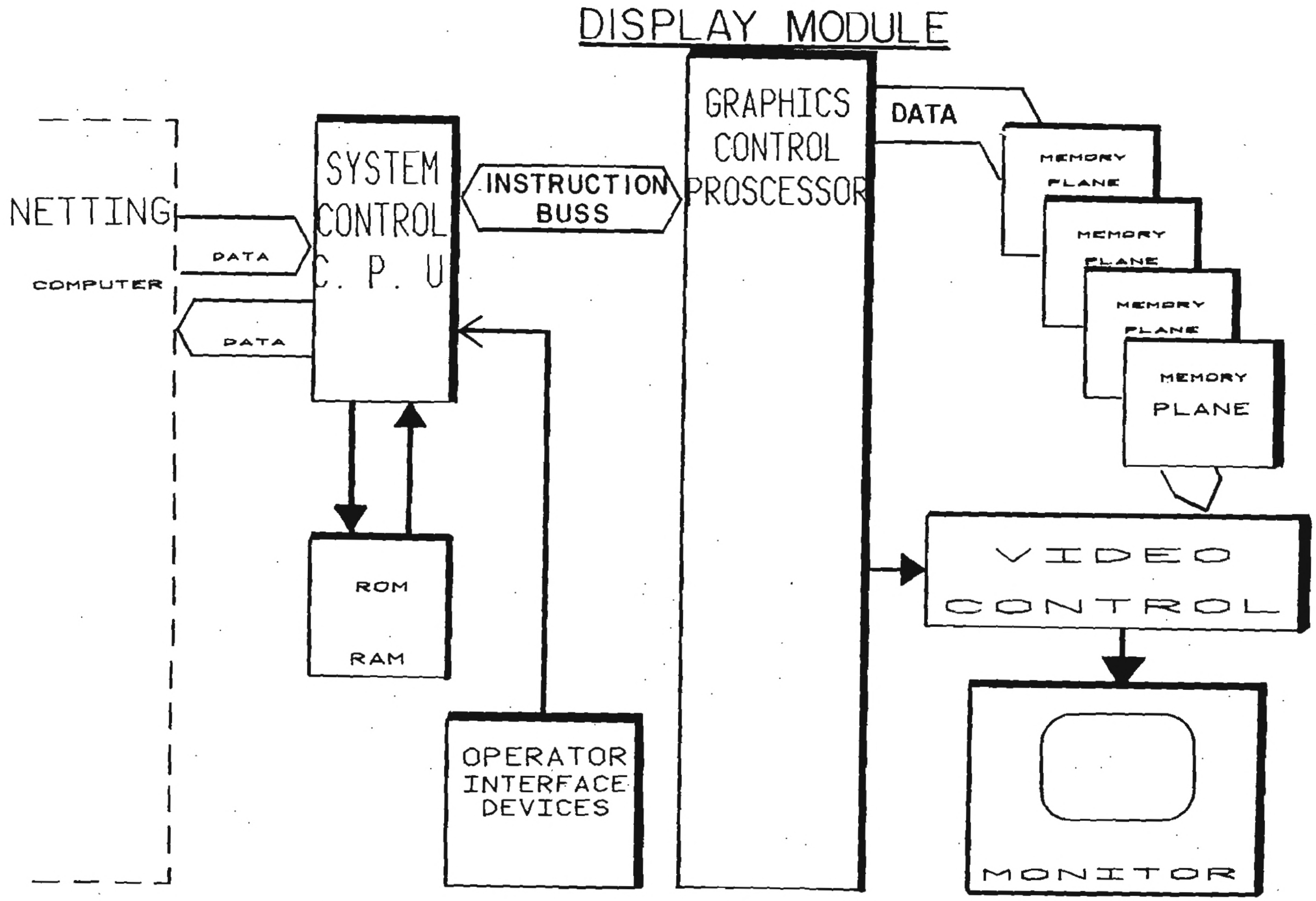


Figure 14. Block diagram of display module components.

(ROM) would be required for algorithm storage and random access memory (RAM) would be included for use as storage buffers. The messages sent from the netting computer to the system control CPU would, in some cases, be converted to machine language by the system control CPU before being sent to the graphics processor controller (GPC).

The GPC exercises vector graphic firmware routines. When given X and Y coordinates, these routines compute the point on the screen where the pixels that represent the target will be displayed. The vector graphics routines also compute symbology shapes and the updated coordinates required to move the symbols. The GCP also determines how the data will be written to the screen. Symbology would be stored by category in a full capability system.

The displayed screen is written from memory planes if a raster format display is used. An expensive, top of the line display system may have up to 16 full screen areas that can be dedicated to four types of symbology.

During the screen refresh cycle, the GCP may cause the data in any of the screen refresh memory planes to be written sequentially or in interlaced fashion by the video controller. The screen picture assembly process is managed by the video controller. The assembled screen picture is then sent as composite video to the monitor. The monitor shown in Figure 14 is conceptualized as a standard raster scan cathode ray tube monitor, although other types of displays should be considered in the final design. The types of displays are discussed in a following subsection.

The display concept under consideration involves several potential levels of display capability based on the number and type of sensors which are included in the netted system. These levels are indicated in Figures 15 through 17. In Figure 15, all of the sensors are point sensors with the associated low data rates and low resolution display requirements. Thus, the three sensor types are netted together through the netting computer which is then interfaced to the FIDS display which should be capable of handling these additional point sensor inputs. In Figure 16, the FIDS sensor system is shown to be netted with at least one radar and a simple netted display is provided on the primary display system. The FIDS display unit may be used as an auxiliary display unit. In Figure 17, the scenario includes multiple sensor types including some FIDS sensors for either fixed-base or mobile deployment applications. For this case, a full capability netted display would be required. For the mobile deployment mode, radar sensors make much better sense than fixed sensor since they can be deployed much more rapidly.

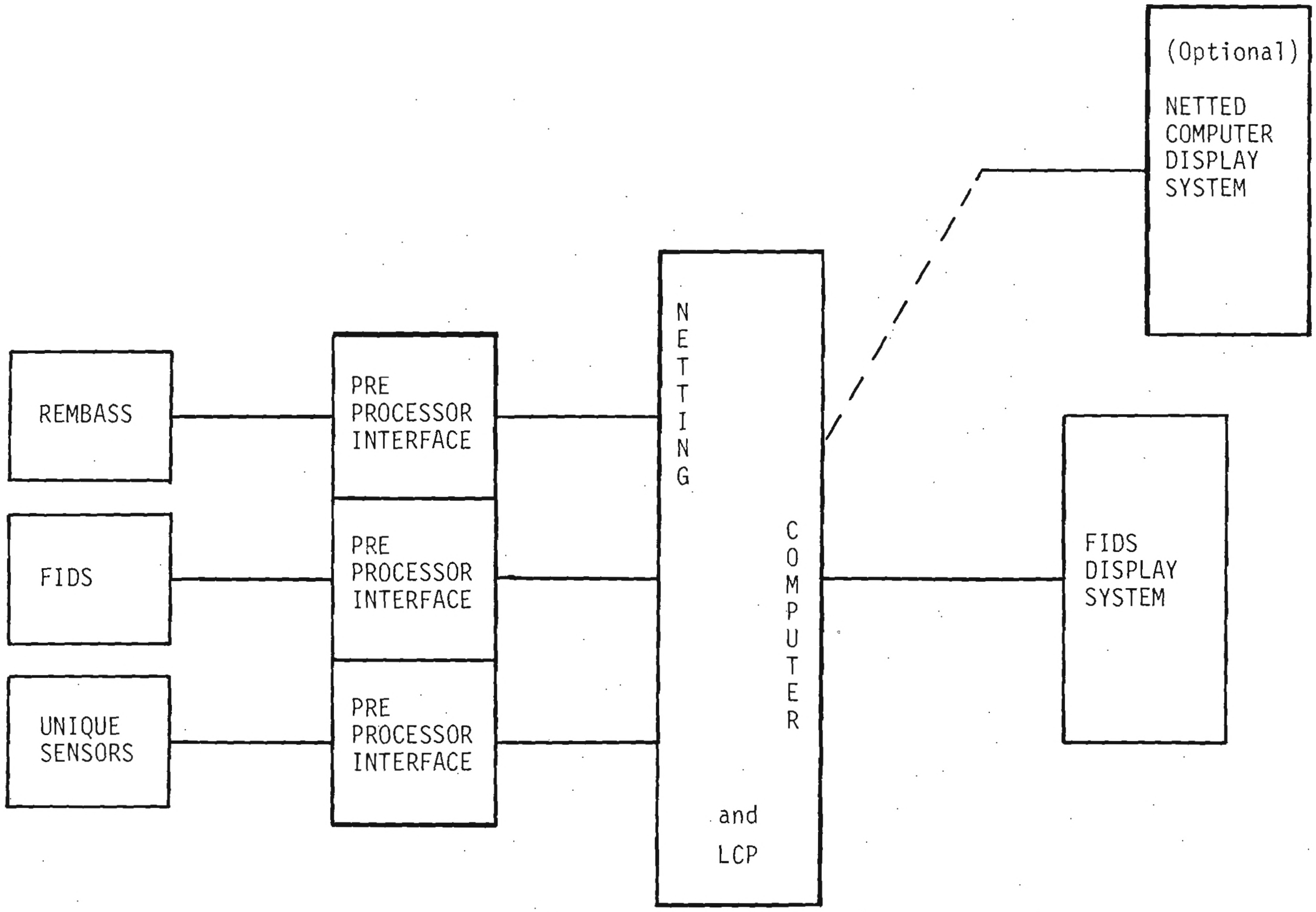


Figure 15. Fixed base system using netting computer as primary sensor sampler and control system driving FIDS display system as primary display.

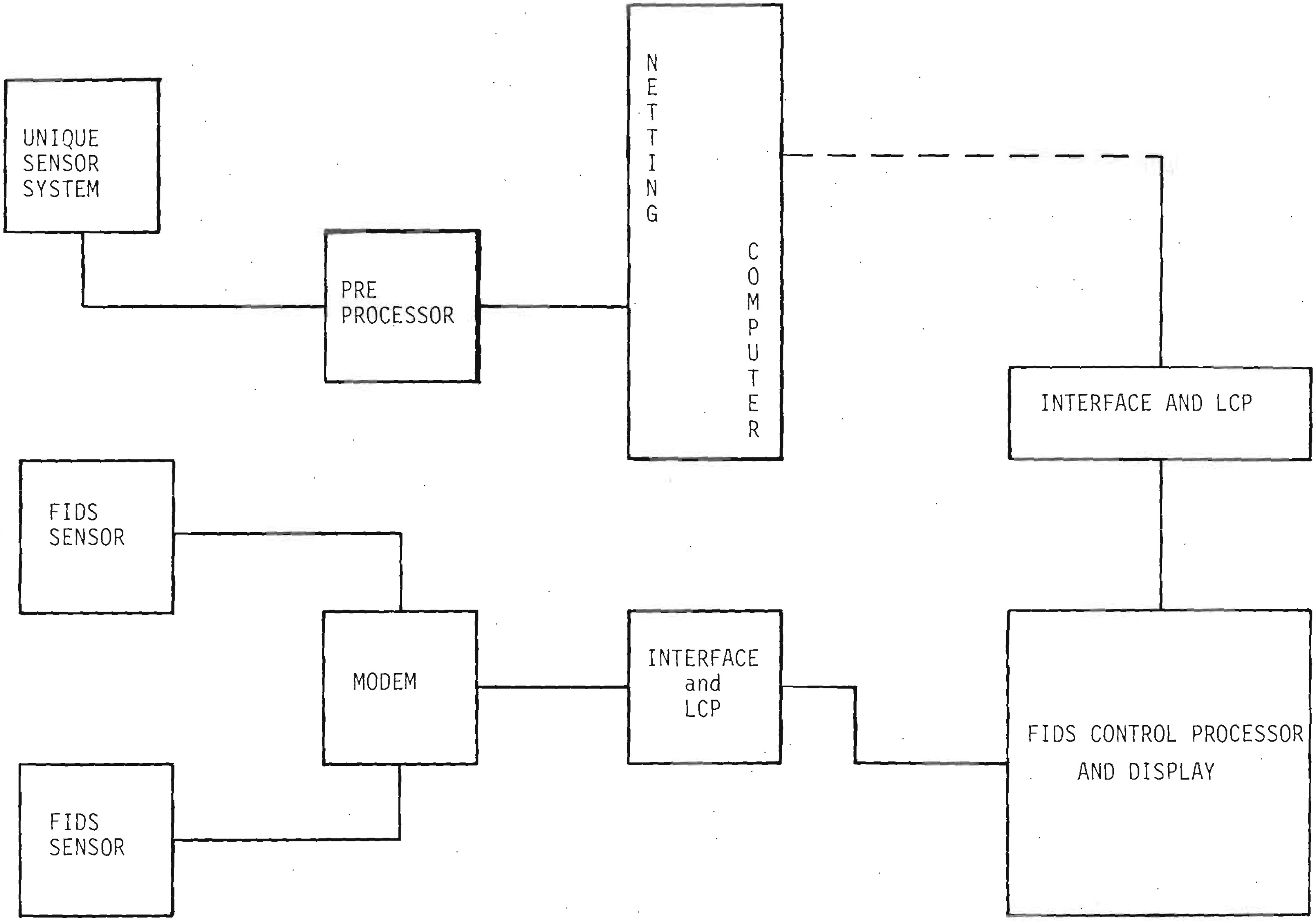


Figure 16. Level 1 Fixed Base System Using No Radar but Unique Sensor(s) and Netting Computer Tied to Primary FIDS System.

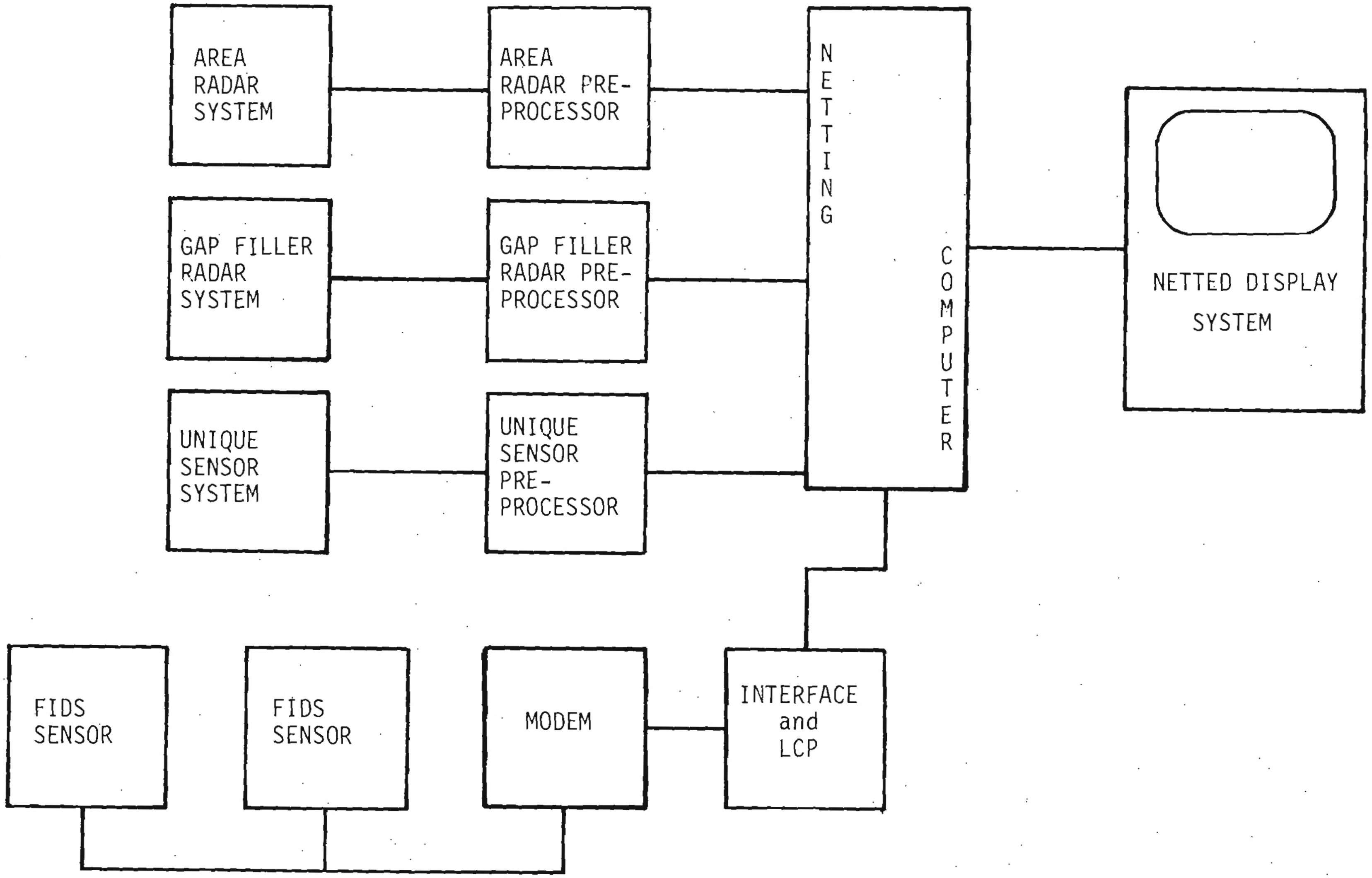


Figure 17. Fixed base or mobile deployment concept includes area radar, gap filler, unique sensor, and FIDS sensors, but no FIDS stand alone sensor.

4.4 COMMUNICATION OF DISPLAY DATA

One purpose of the netting computer is to process data from sensors and format the resulting information for transmission to the system control CPU in the display system module. Since several levels of display system sophistication may be specified (depending on overall security system size), it is desirable to utilize a rigid data format for the data transmitted between the netting computer and the display system CPU. The use of a rigid format allows certain data fields to be accessed quickly, thus improving display response times. In addition, a rigid data format allows certain data fields to be ignored by less sophisticated versions of the display system.

A fixed byte word was chosen as the basic data unit. The bit count in the fixed byte word is dictated by the number of bits in the netting computer standard word.

Table 12 shows the conceptual structure of the data sent between the netting computer and the display system control CPU. There are two message preamble catagories and four types of messages. Each preamble message is defined as a header. The message structure is defined as a data block.

The status header contains the frame ID number, time of transmission, total alarms being reported, total sensors failed, total sensors out of service, total tampers, and total IFF reports. This status header information is used to determine if any additional data in the frame should be read. For example, if there are no data changes between updates, the redundant information of the previous transmission can be ignored. The status header also provides information that a less sophisticated display system or a slave display might use for total system information.

The pointer header block allows data to be efficiently transmitted and read. The data words within the pointer header block specify or point to the word in the variable length data stream where data words of interest are found. For example, if there are no device failures there will be no failure reports in the data stream during the transmission of frame N, however, should three sensors fail before the transmission of frame N+1 the failure pointer will specify the location of the three failure messages in the data stream. The efficiency gained by using the variable length data frame can be demonstrated.

The total byte count in frame N would be 15 bytes less than during frame N+1. Only the data blocks that change are transmitted. The change order appears on the data buss only after the change has occurred. The system control CPU maintains an updated list of system parameters on a local basis and updates these parameters when a change occurs. This procedure reduces the time required for the netting computer to service the display system CPU by reducing the amount of data exchanged between processors.

TABLE 12. THE STRUCTURE AND ORDER OF THE DATA BLOCKS SENT FROM THE NETTING COMPUTER TO THE DISPLAY MODULE SYSTEM CONTROL CPU.

STATUS HEADER

FRAME I.D. NUMBER	TIME THAT FRAME SENT	TOTAL ALARMS BEING REPORTED	TOTAL SENSORS FAILED	TOTAL SENSORS OUT OF SERVICE	TOTAL TAMPER CONDITIONS REPORTED	TOTAL I.F.F. REPORTS	E O B

POINTER HEADER

FAILURE OR OUT OF SER-VICE DATA POINTER	SENSOR TARGET DATA POINTER	I.F.F. DATA POINTER	TAMPER DATA POINTER	FUTURE EXPANSION	E O B

WRITTEN ONLY WHEN STATUS CHANGES

FAILURE OR OUT OF SERVICE DATA BLOCK

DEVICE I.D. NUMBER	CODE FOR STATUS (FAILURE OR OUT OF SVC)	TIME EVENT OCCURRED	CODE THAT REPRESENTS THE TYPE OF MESSAGE	FUTURE EXPANSION	E O B

SENSOR TARGET DATA BLOCK

TARGET I.D. NUMBER	SENSOR I.D. NUMBER	X-COORD OF TARGET	Y-COORD OF TARGET	ALERT STATUS CODE	TARGET VELOCITY	SIGNAL QUALITY	FUTURE EXP.	E O B

TAMPER DATA BLOCK

REPORTING SENSOR I.D. NUMBER	CODE THAT DESCRIBES TAMPER ACTIVITY	REPORT NUMBER	TIME OF FIRST REPORT	E O B

IFF DATA BLOCK

TRANSPONDER I.D. CODE	REPORT NUMBER	TRANSPONDER X-COORDINATE	TRANSPONDER Y-COORDINATE	E O B

Table 13 shows how the status header is organized. Table 14 shows the organization of the pointer header data block. Table 15 presents the organization of the failure or out of sevice data block. Table 16 shows the organization of the sensor target data block. Table 17 is a summary of the organization of the tamper data block. Table 18 shows how the IFF data block is organized.

4.5 DATA DISPLAY FORMATS ACHIEVABLE WITH A FULL CAPABILITY SYSTEM

The display serves as the operator's interface with the physical security system. The operator will make most of his decisions on the basis of the data presented by the display. Thus, the maximum amount of data available should be presented to the operator in as highly graphic format as possible. Complex decisions as to message formats can be made within the display unit on the basis of very brief "flag" words from the sensor. The netted system concept utilizes this capability to advantage.

Figure 18 shows a simulated display screen area and the status function options. There are three system status conditions: (1) secure and operational, (2) tamper alert, and (3) system failure. The status display alerts the operator to specific system conditions that the operator should be aware of at all times. Normally, only the secure and operational message would be displayed unless a tamper alarm was in progress or a system failure occurs.

Figure 19 shows a full display format during a tamper alert notification. The system status indicator shows that a tamper situation is in progress. The billboard area to the left of the system status area provides the operator with pertinent data relating to the tamper alarm. A map of the base provides visual reference information. The map presentation allows the operator to locate and quickly reference the sensor reporting the tamper condition. In addition, the location of security units are shown (security units 301 and 320 are assumed to be transponder equipped). A 1-minute location vector is projected from security unit 301 on the basis of the units speed derived from historical transponder track file information. The 1-minute location projection line allows the operator to determine in which direction the security unit is moving and it's length also provides a rough estimate of time of security force arrival.

Figure 20 shows how an intentional entry might be displayed. The system status indicator shows that the system is secure and operational. The billboard area however shows no sensors are off line for service, but three sensors out of 183 have been turned off to provide personnel access to a specific facility. The map area shows that the approved entry is into weapon hut three, and that the authorization for entry can be

TABLE 13. STATUS HEADER ORGANIZATION

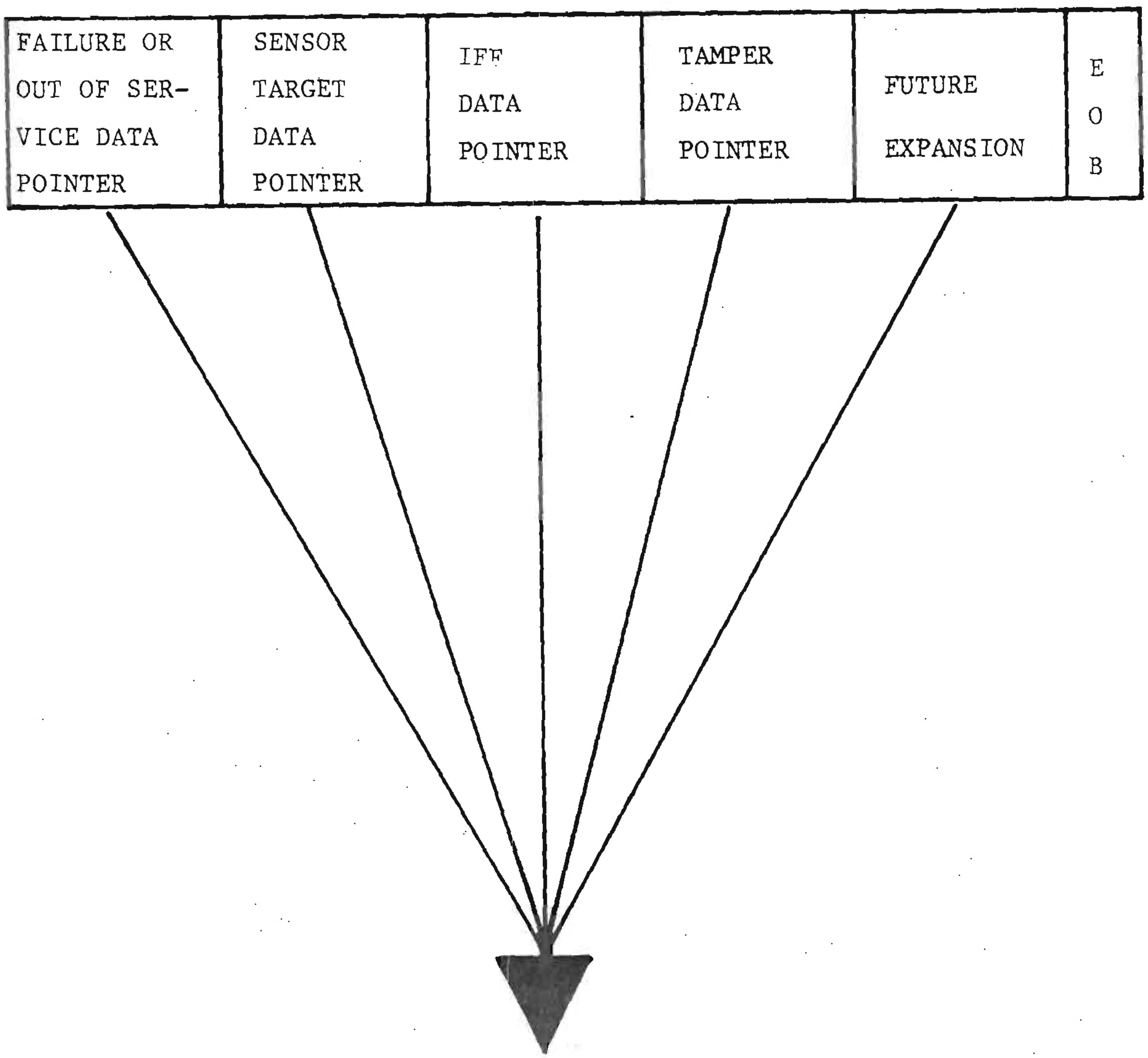
FRAME ID NUMBER	TIME THAT FRAME SENT	TOTAL ALARMS BEING REPORTED	TOTAL SENSORS FAILED	TOTAL SENSORS OUT OF SERVICE	TOTAL TAMPER CONDITIONS REPORTED	TOTAL IFF REPORTS	E O B

IF EACH CATEGORY IS ZERO, READ NO FURTHER INTO DATA BLOCK. IF ANY NOT ZERO, THEN TOTAL COUNT MUST AGREE WITH TOTAL OF REPORTS READ FROM DATA BLOCKS, OR TEST CRITERIA NOT MET AND SYSTEM FAILURE INDICATED.

THIS IS TIME OF DAY KEPT IN SYSTEM TIME CODE FORMAT.

ID NUMBER OF FRAME. THIS NUMBER INCREMENTS BY THE COUNT OF ONE EACH TIME THE NETTING COMPUTER SENDS A FRAME TO THE DISPLAY MODULE. FRAME SEQUENCE RESETS TO ZERO WHEN ALL TOTALS ARE ZERO.

TABLE 14. POINTER HEADER ORGANIZATION



EACH POINTER TELLS THE DISPLAY SYSTEM WHERE TO FIND THE FIRST WORD IN THE FIRST DATA BLOCK OF INTEREST. THIS FEATURE ALLOWS A VARIABLE LENGTH DATA STREAM TO BE COMPOSED OF ONLY THOSE DATA BLOCKS REQUIRED.

TABLE 15. FAILURE OR OUT OF SERVICE MESSAGE DATA BLOCK ORGANIZATION

DEVICE ID NUMBER	CODE FOR STATUS	TIME THAT EVENT OCCURRED	CODE THAT REPRESENTS TYPE OF MESSAGE	FUTURE EXPANSION	E O B

(SYSTEM RESERVE)

1. POWER FAILURE
2. SENSOR FAILURE
3. DATA LINK FAILURE
4. SELF-TEST RESULTS BELOW ALLOWED
5. SENSOR PURPOSELY OFF
6. SENSOR REMOVED FOR REPAIRS, TEST, OR OTHER REASON

TIME OF DAY THAT FAILURE OR PURPOSEFUL REMOVAL OF SENSOR FIRST OCCURRED

CODE THAT INDICATES THAT EITHER A SYSTEM FAILURE HAS OCCURRED OR THAT THERE ARE CERTAIN SENSORS NOT RESPONDING DUE TO PURPOSEFUL REMOVAL FROM THE SYSTEM

UNIQUE NUMBER ASSIGNED SYSTEM COMPONENT (SENSOR) AT TIME OF INSTALLATION

TABLE 16. SENSOR/TARGET DATA BLOCK ORGANIZATION

TARGET ID NUMBER	SENSOR ID NUMBER	X-COORD OF TARGET	Y-COORD OF TARGET	ALERT STATUS CODE	TARGET VELOCITY	TARGET VELOCITY	E O B

FOR FUTURE EXPANSION AND ECM DETECTION

THE TARGET VELOCITY AS COMPUTED BY THE NETTING COMPUTER IF DETECTION MADE BY RADAR

THIS CODE DESIGNATES PRESENT CATEGORY OF YELLOW ALERT OR RED ALERT. EXPANDABLE TO HANDLE THREAT ASSESSMENT MESSAGE

THE Y GRID COORDINATE OF TARGET LOCATION. THE Y COORDINATE IS SAME AS POINT SENSOR LOCATION IF REPORT IS FROM POINT SENSOR

THE X GRID COORDINATE OF TARGET LOCATION. THE X COORDINATE IS SAME AS POINT SENSOR LOCATION IF REPORT IS FROM POINT SENSOR

ID NUMBER OF SENSOR REPORTING TARGET

THE IDENTIFICATION NUMBER ASSIGNED TO THE TARGET WHEN IT APPEARS THE FIRST TIME. THIS NUMBER IS BASIS ON WHICH ASSOCIATED TARGET TRACK FILE IS ESTABLISHED

TABLE 17. TAMPER DATA BLOCK ORGANIZATION

REPORTING SENSOR ID NUMBER	CODE THAT DESCRIBES TAMPER ACTIVITY	REPORT NUMBER	TIME OF FIRST REPORT	FUTURE EXPANSION	E O B

(FUTURE NEED)

TIME OF DAY WHEN SENSOR TAMPER MESSAGE WAS FIRST SENT.

NUMBER THAT INCREMENTS EACH TIME REPORT SENT.

1. REMOVAL
2. MOTION
3. OPENING OF ACCESS COMPARTMENTS
4. SHOCK (GREATER THAN 1 G)
5. FIRE
6. JUMPERING OR DISCONTINUITY CONDITION

THE UNIQUE IDENTIFICATION NUMBER OF SENSOR REPORTING A TAMPER ALARM.

TABLE 18. IFF DATA BLOCK ORGANIZATION

TRANSPONDER ID CODE	REPORT NUMBER	TRANSPONDER X-COORD	TRANSPONDER Y-COORD	FUTURE EXPANSION	E O B

FOR FUTURE USE

THE TRANSPONDER Y COORDINATE DERIVED BY THE POLAR TO RECTANGULAR CONVERSION ROUTINE.

THE TRANSPONDER X COORDINATE DERIVED BY THE POLAR TO RECTANGULAR CONVERSION ROUTINE

THIS IS A COUNT THAT INCREMENTS BY ONE ANY TIME ANY IFF DATA BLOCK APPEARS AS A MESSAGE. RESET AT INCREMENT TO BE DECIDED.

THIS IS THE UNIQUE TRANSPONDER ID NUMBER ENCODED ON THE TRANSPONDER'S REPLY TO INTERROGATION.

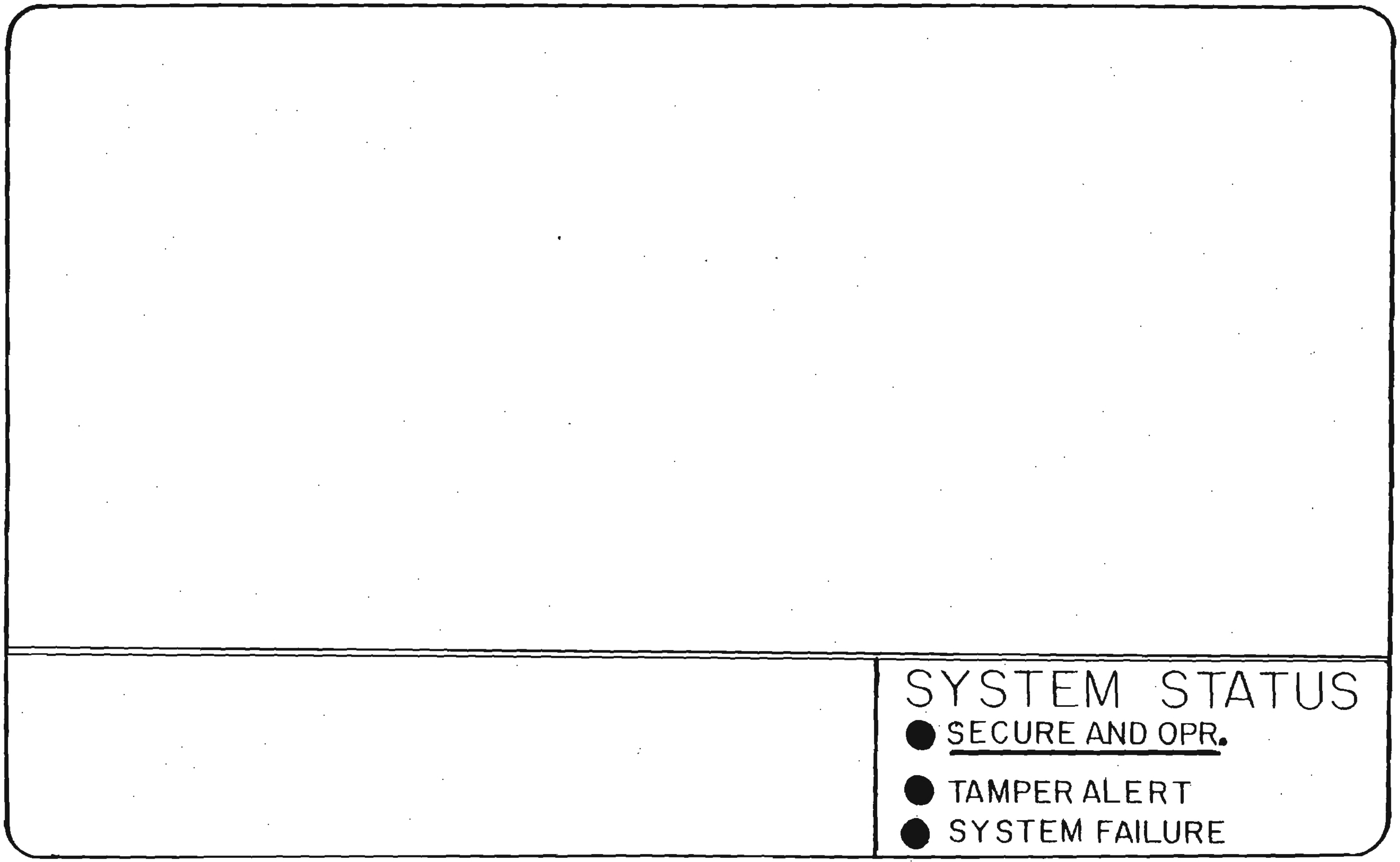


Figure 18. Simulated display with status codes shown.

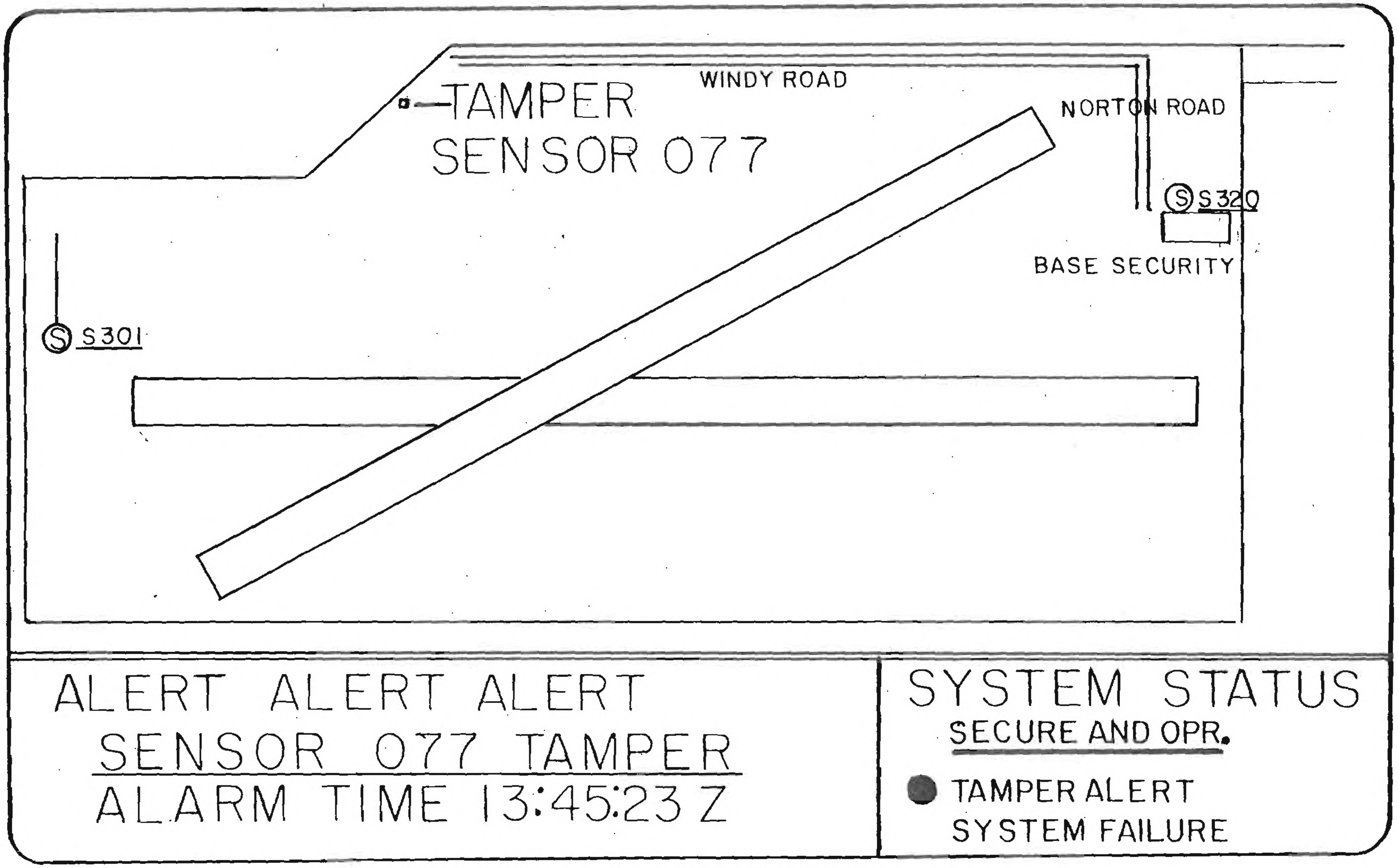


Figure 19. Simulated display for TAMPER condition.

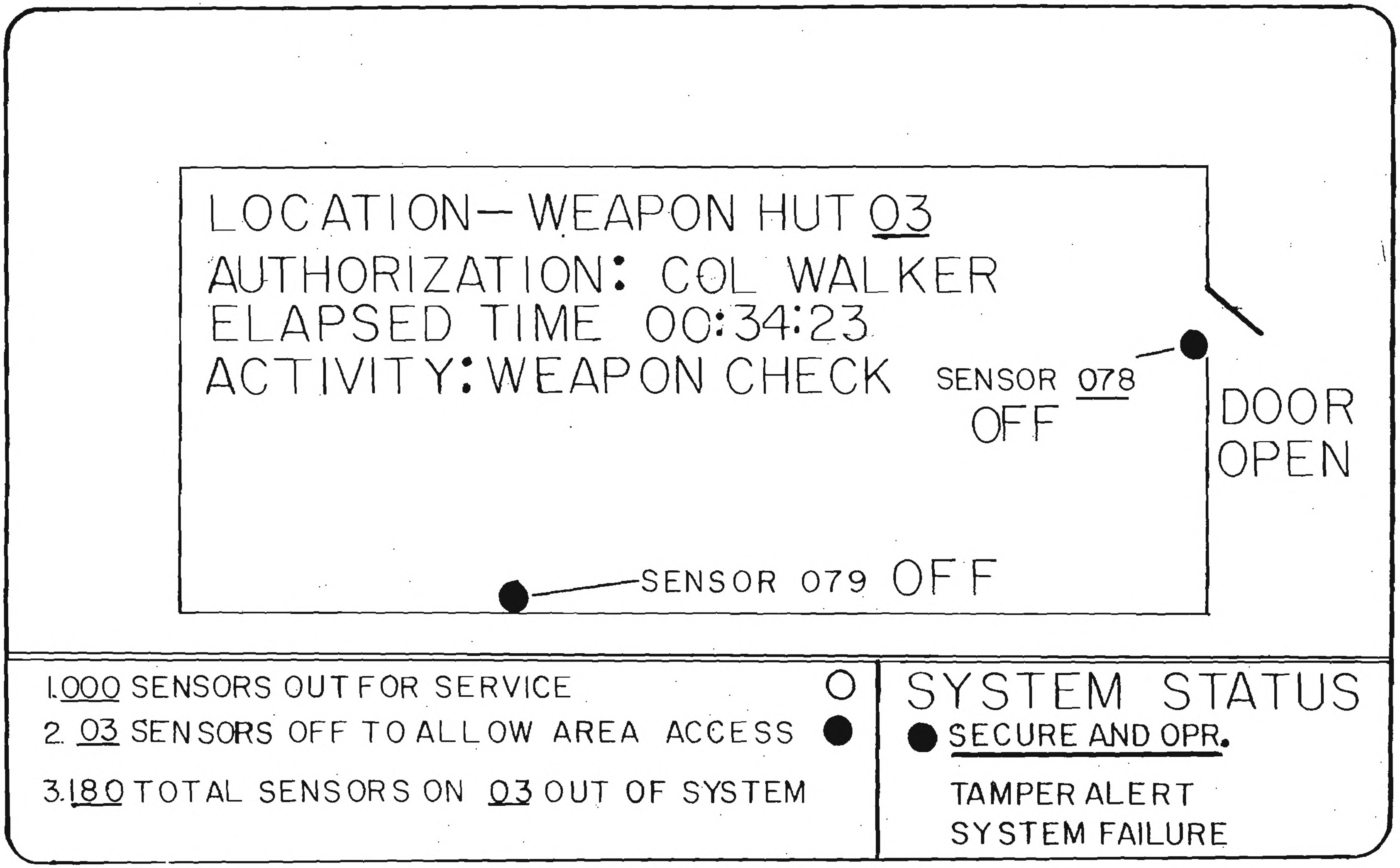


Figure 20. Simulated display for intentional entry.

verified by Colonel Walker (when an entry occurs, procedures would be followed to verify and authenticate the process). A timer would be started to show elapsed time since first entry, and the type of activity would be shown. The sensors that were taken off line to allow entry would also be shown. All of this information could be preserved as an historical record of entries if a mass storage device was associated with the display driver computer.

Figure 21 shows the display when sensor failure has occurred. The system status indicator shows that system failure has occured. The billboard shows that no sensor associated processors are out of service; three sensor units have failed; the identification numbers of the failed sensors are 120, 122, and 125; the elapsed time since failure is 12 minutes 34 seconds; and system maintenance personnel were called at 0128:45 hours Zulu. The time that the maintenance personnel were called would be entered by the operator via the keyboard. The map area displays the failed sensor locations automatically because the failed sensors can not reply to the system status interrogation message.

Figure 22 shows a simulated display at the time of an intrusion detection. The system status monitor informs the operator that the system is secure and operational; thus all alarm data should be accepted as valid. The billboard shows a simple but easily readable message fomat. The ALERT ALERT ALERT message would flash on and off. The sensor type and number would also be displayed. The alarm type would be shown; in this case INTRUDER. The time of first intrusion detection is shown as ALARM TIME, which is 1545:23 hours Zulu.

The map would display major landmarks and the location of the transponder equipped security force (units S320 and S310).

Since radar was the detector of the intruder's presence, the intruder's location can be determined with precision. The intruder's location is marked by a circle. The symbol within the circle in the example case is an I for intruder. The data produced by the radar allow target velocity and location to be computed on a scan-to-scan basis. Thus, targets may be identified within the general catagory of low velocity (speed $<$ 3 kts) and high velocity (speed $>$3 kts) targets.

If coherent (Doppler) radar data are used, other target recognition techniques might be employed to identify targets by Doppler signature. Given this capability, an I might be assigned to low speed targets to symbolically represent an intruder on foot, based on the detection of arm and leg motion. A V might be assigned to symbolically represent the presence of an intruder in a vehicle, based on the strong Doppler associated with a vehicular size target.

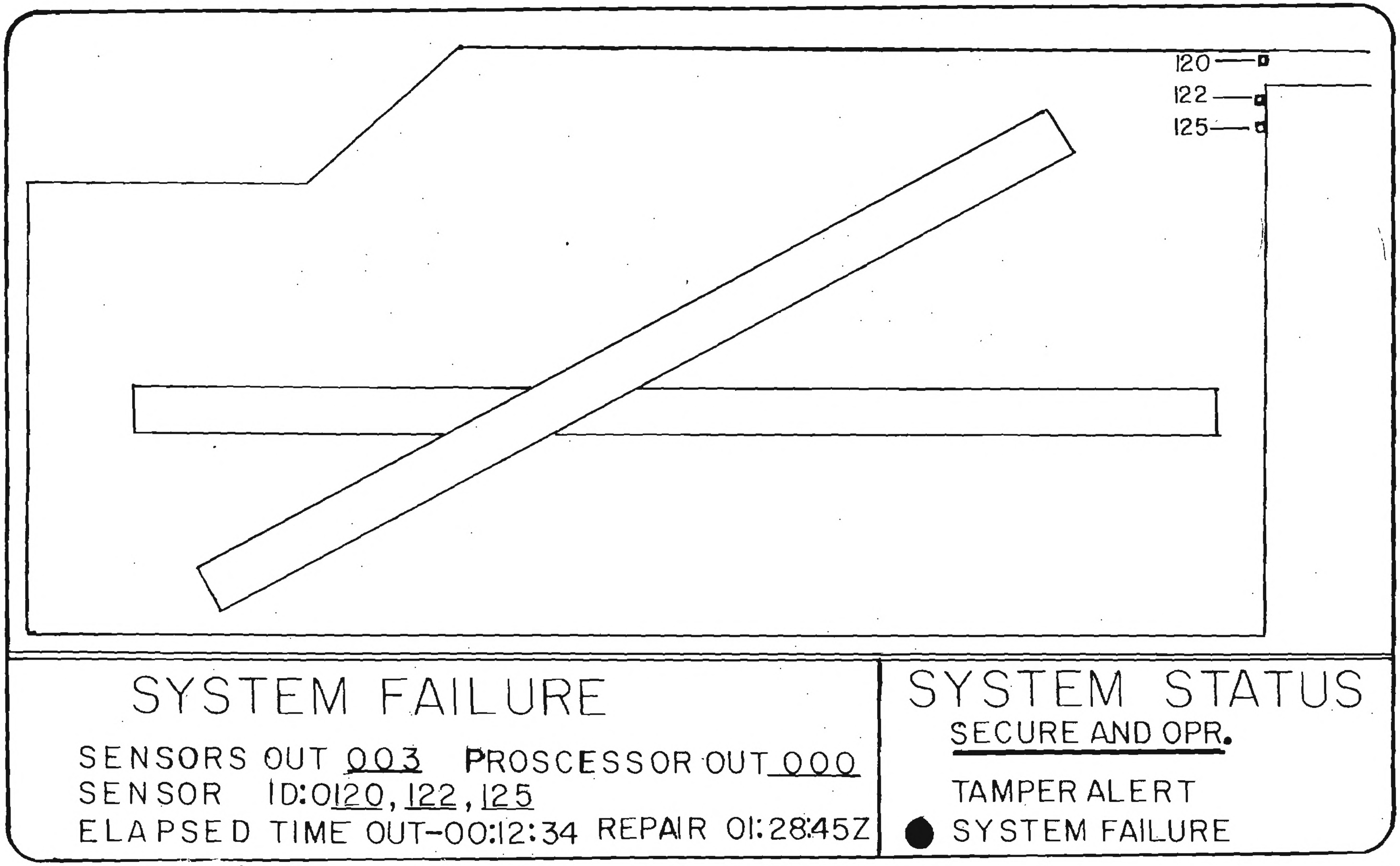


Figure 21. Simulated display for a system failure.

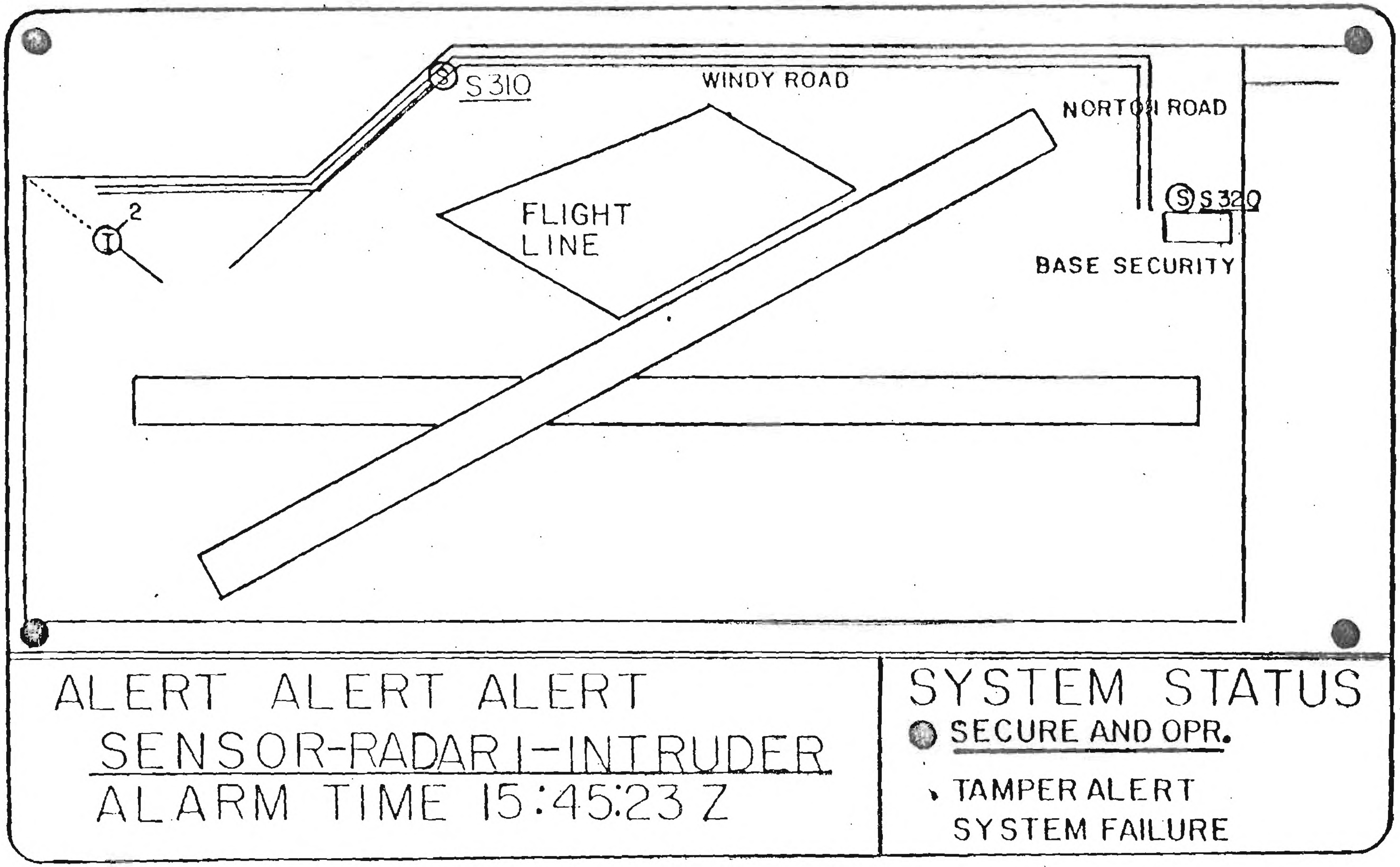


Figure 22. Display unit presentation when intruder has been detected by radar in net.

The dots behind the intruder would represent a smoothed track history (in this case, the last 8 computed intruder locations). The line ahead of the target would represent the time track line. The direction of movement would be indicated by the pointing angle of the time track line, while the intruder's location at a point 60 seconds in time would be indicated by line length (the end of the time line represents location in 60 seconds). The number above the target symbol would be a numeric presentation of computed target speed.

Four dots are shown; one in each corner of the screen. These are light pen or touch panel activation points. The display parameters could be changed quickly by activation of these points. This rapid response feature is necessary to allow the operator to devote maximum attention to the displayed information while requiring minimum display manipulation.

Figure 23 shows the results of activating one of these touch panel or light pen points. A blow-up of the intrusion scene is shown. Additional data are provided in the billboard display area. The operational mode is shown; the elapsed time since intrusion detection is also shown. The security unit responding to the intrusion is shown along with that units estimated time of arrival (based on track history). The sensor detecting the intruder is also shown; in this case, a wide area radar. Two additional light pen or touch panel activation points are provided in the billboard area. The activation point labeled main map returns the system to display the information presented in Figure 22. The activation point labeled Billboard 2 will display a security grid reference system or other desirable map presentation. Figure 24 shows the grid mode presentation. The grid mode representation would be a useful tool to vector security forces to a particular sector. The only difference between a normal map presentation is that grid coordinates are substituted for map coordinates, in the example display, the intruder symbol has been changed to M to represent man. Assuming that a coherent area radar is used as the sensor and the radar has an associated Doppler processor, then actual target type can be inferred from the Doppler signature.

Each of the display concepts depicted in Figures 17 through 24 can be implemented using currently available technology. The level at which any of the display concepts could be implemented is limited only by cost. The intruder type, approximate location, and speed would only be available to the display when an area radar is used with the system. A transponder system would be necessary to track the security force and project security time lines.

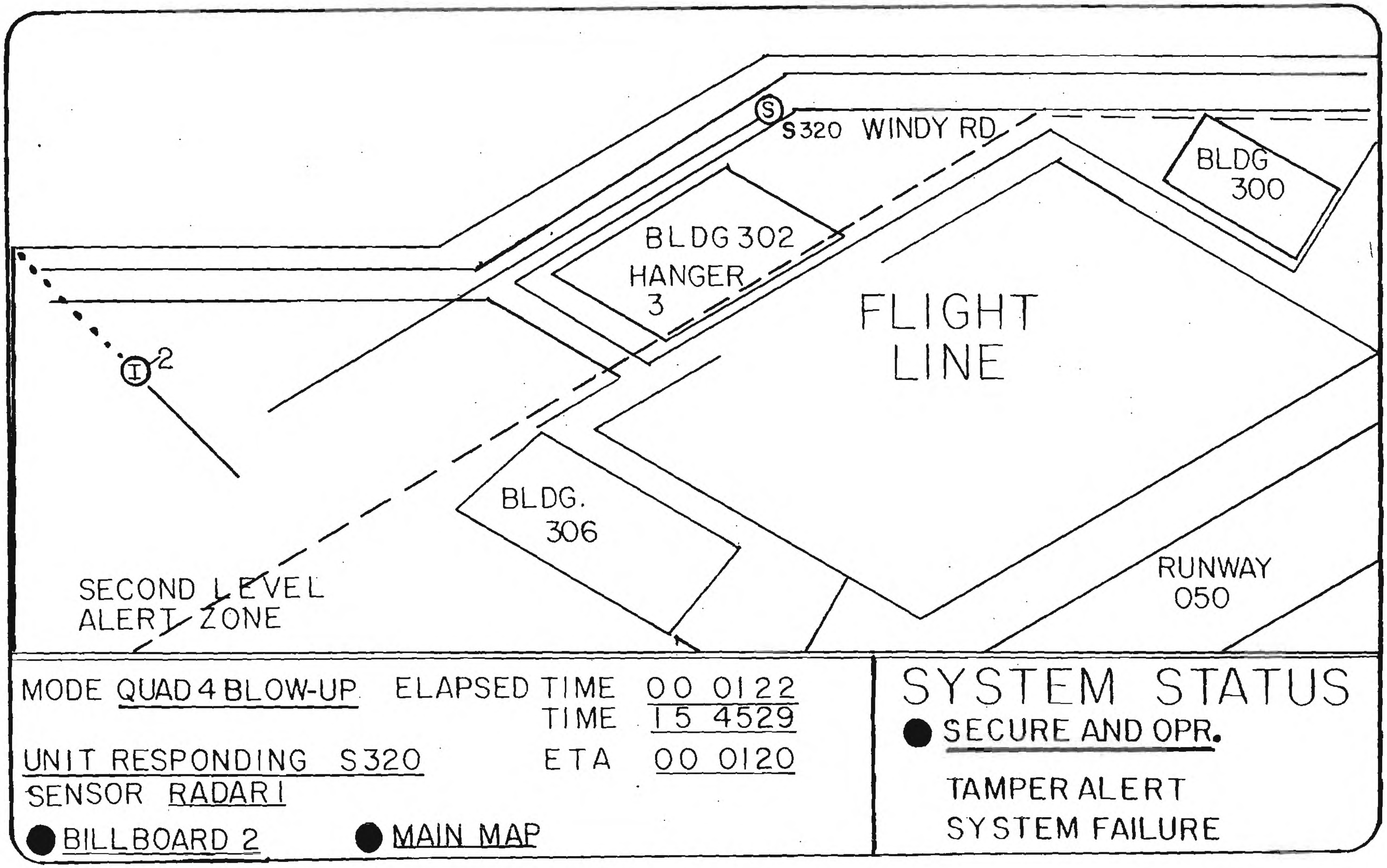


Figure 23. Display unit simulation showing results of activating the blow-up mode on the display.

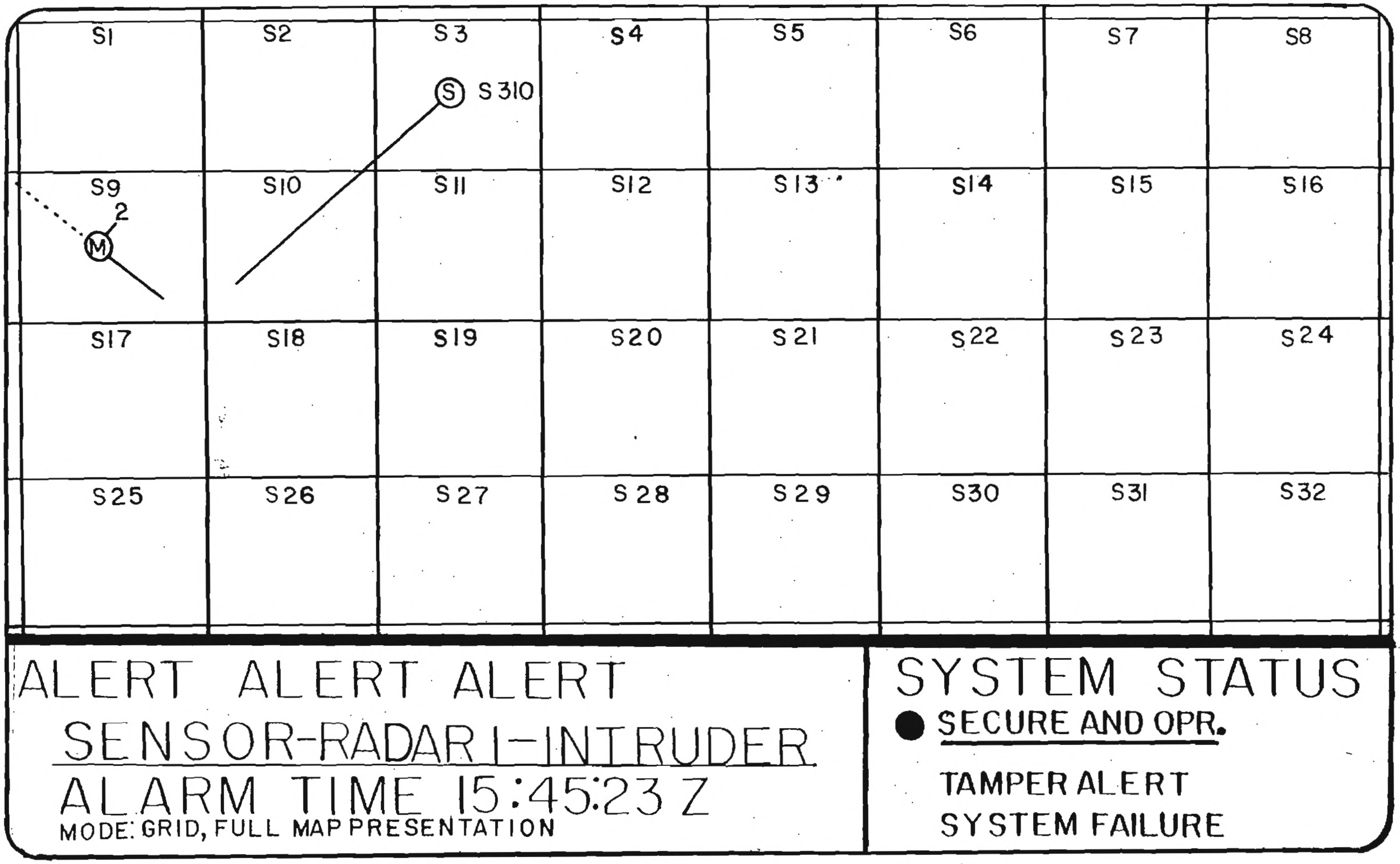


Figure 24. The display unit presentation in the grid mode.

4.6 DISPLAY TECHNOLOGY

4.6.1 OVERVIEW

Five state-of-the-art display technologies are candidates for use as the display unit in the netted security system display module. Each technology has associated advantages and disadvantages which are application and requirement dependent. One of these display technologies will ultimately be selected for use in the final netted security system module after final system requirements are established.

The technology utilized to display information from the netted security system (in formats proposed earlier) is available on an off-the-shelf basis. This availability forecast is supported by a survey of state-of-the-art display systems that is included as Appendix C of this report. This survey was developed as a task supported by this research project.

Five display device technology categories were surveyed. Over 75 candidate display devices were included in the survey as shown in Appendix C. In addition, literature on most of these display devices was obtained from the manufacturer of record and this information was consolidated into a display device compendium which resides at Georgia Tech. The specifications that were surveyed and shown in Appendix C, include the following: (1) manufacturer, (2) model, (3) date that the system was introduced, (4) resolution (pixel array size), (5) number of displayable colors, (6) total associated memory, (7) supporting software options, (8) operator/system interface devices (input/output), (9) associated mass storage devices, and (10) price.

The display systems listed in Appendix C, are organized by technology type. Five basic types of technology are used as the display device in the display module. They are: (1) storage tube, (2) stroke writer, (3) plasma panel, (4) light emitting diode panel, and (5) the raster scan display. Each technology has advantages and disadvantages which depend on final application. The following paragraphs discuss the principles on which each of the five technologies operate, and their advantages and disadvantages.

4.6.2 STORAGE TUBE

The storage tube display was first introduced as the display device for the digital computer. Basically an electron beam, controlled in the X and Y direction by magnetic deflection techniques, writes a point on the surface of a storage cathode-ray tube (CRT). When the electron beam strikes the phosphor coating on the screen, the phosphor is excited and photons are emitted by the phosphor. The phosphor remains in an excited state, emitting photons, until an excitation voltage is removed from the screen. Thus, the excited screen area serves as a memory and it emits light at each point where the electron beam has excited the phosphor. Memory and photon emission are maintained until the screen memory control voltage is removed from the screen surface area. The maximum resolution that can be achieved is determined by beam spot size and total screen area.

There are advantages to using a storage tube display. There is no need to periodically update or refresh the screen. Once excited, the pixel appears as a luminous point until the screen maintenance voltage is removed. High resolution can be obtained as pixel size is only a function of magnetic focus capability. A third advantage is that there is no specific scan pattern required during the writing to the screen. Any pixel area may be illuminated at any point on the screen upon command from the associated electron gun driver electronics.

Storage tube displays also have disadvantages. The storage tube display is primarily a low light output device. High ambient light levels will wash out the display. The entire screen must be erased to erase any pixel already written on the screen; for certain applications, this can be a major problem. The display is limited to a single color (green), which eliminates the possibility of color coding of display features. Most storage tubes are short lived devices when compared to other types of displays. When a storage tube fails, the replacement cost is high.

4.6.3 STROKE WRITER

The stroke writer is another CRT display device. The display of conventional CRT with high brightness phosphor is written by an electron beam steered in X and Y coordinates. The phosphor may be medium or long persistence. Just as with the storage tube, the electron beam is steered to any location where a pixel is to be written. The beam steering instructions are controlled by software computed vector graphics routines.

There are advantages to using stroke writer technology. The combination of high energy electron beam and high intensity phosphors allow operation in high ambient light level environments. There is a low refresh memory overhead if all beam steering vectors are computed from X-Y coordinates during each screen refresh cycle. The stroke writer is also capable of high resolution.

There are disadvantages to using stroke writer technology for certain applications. At present, there are only three color phosphors available. The refresh rate slows as the number of pixels to be displayed increases. When the refresh time exceeds phosphor persistence times, a flicker of the screen is noticeable.

4.6.4 PLASMA PANEL

The plasma panel display does not use CRT technology. The plasma panel is composed of a front and a rear optically clear panel mounted in a vacuum seal structure. An ionizable gas occupies the small area between the front and rear panels. A matrix of very small conductors run parallel to the screen surface in an X and Y plane. When a voltage is applied to an X and Y pair, the gas at the intersection of the conductors becomes excited and the gas glows.

There are advantages to using the plasma panel for certain applications. The plasma panel is a flat screen and does not require a recessed cabinet for installation. The panel can be used as a rear or front projection screen. Maps, facility outlines, or other graphics can be optically projected onto the screen surface. Plasma panel data can then be displayed using the projected map graphics data as visual reference points. The plasma panel is rugged and well suited for military application. The rugged design also makes it well suited for mobile or portable applications.

The plasma panel does not require continuous update. The logic that drives the X, Y screen locations can be selectively latched and unlatched (erased) when the status of individuals pixels change.

The plasma panel has disadvantages for certain applications. The current generation of plasma panels display only a single color. There is no grey scale; a pixel is either on or off.

The plasma panel is a low light output device and must be operated under subdued ambient light conditions. This limitation suggests that, if the display application requires operation in direct sunlight, a plasma panel may not be the best choice of display mediums.

4.6.5 LIGHT EMITTING DIODE (LED) PANEL

A recent addition to the family of display mediums is the light emitting diode (LED) display panel. The LED panel is composed of individual chips of Gallium Arsenide (GAs) that will emit photons (light) when excited by a low voltage. The color emitted by Gallium Arsenide is in the red region of the visible spectrum. However, if the GAs is doped with other semiconductor materials, different colors can be obtained.

The LED panel is composed of an array of light emitting diode chips that can be addressed in X and Y matrix fashion. It is a rugged display device and can be configured in a flat package.

The latest generation panels provide three colors simultaneously. The matrix encoding scheme allows single LED array elements to be addressed on an individual basis, and each element can be latched in an on condition. The resolution is limited by the density of the number of chips in the array. Total array chip counts are limited by chip size, heat dissipation, and chip connector arrangements. The latest generation LED panel display allow transparent color coded maps and other graphic devices to be put in front of the screen area to further enhance their display capability.

There are disadvantages associated with the LED panel display. The panel is composed of many LED chips that form the array. The current drain is 10 to 20 milliamperes per LED chip (per pixel). Thus, when the screen is filled with data, the panel will draw relatively high current. This factor would be a disadvantage in a portable system or a system where heat dissipation might be a problem. The LED has a relatively low light output. This factor limits the use of the LED to low ambient light level environments.

There is a possiblity that certain LEDs in the array may fail before the active life of the total screen has been exceeded. The pattern in which the LEDs fail would determine if this problem would be a serious limitation.

4.6.6 RASTER SCAN DISPLAY

The raster scan display uses the same display technology that is used in the home television set. Figure 25 shows the pattern scanned by the electron gun in a raster scan display. The electron gun starts at the top of the left hand corner of the CRT, traces a horizontal path to the top right hand corner, and during the flyback period moves back to the far left hand side of the CRT screen and begins to write on the next line down. The entire screen is scanned in this manner from top to bottom 30 or 60 times per second depending on whether retrace is used.

The persistence of the phosphor used with raster scan CRTs is sufficiently long to ensure that the photon emission of a single pixel area will continue until the electron beam returns on the next write cycle to refresh the frame.

Black and white raster scan displays utilize a single hue phosphor that emits monochromatic light. Various hues of color can be displayed using simultaneous excitation of three closely grouped phosphors that emit either red, blue or green.

A combination of the colors red, blue, and green can be mixed in various proportions to produce any color in the visible spectrum. The color or hue that will be produced is directly related to the proportion of the intensity of the three basic colors.

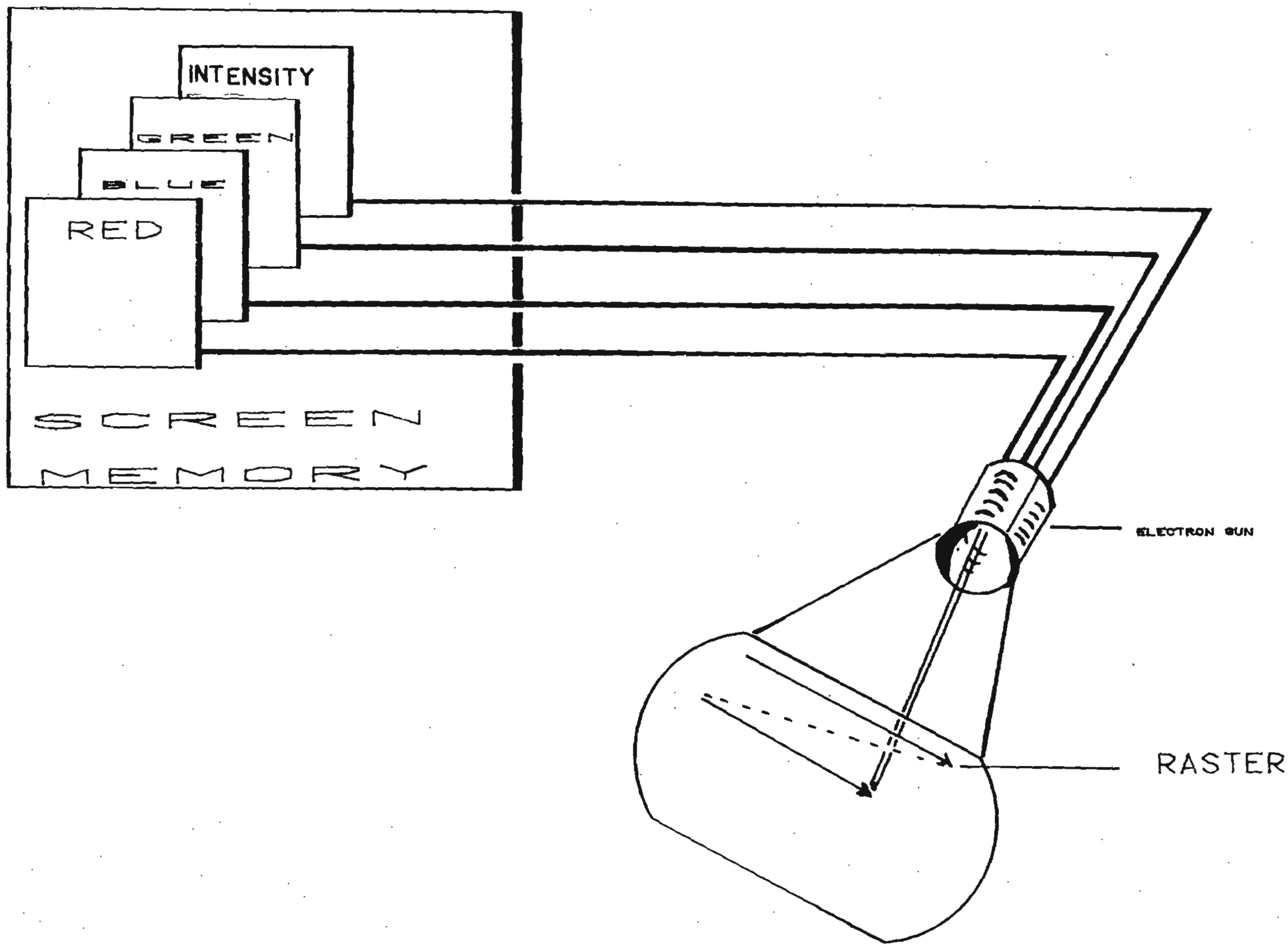


Figure 25. Operational principle of raster scan color display.

The red, blue, and green electron guns track the raster scan line, but each is slightly offset to ensure that only the color pixel controlled by each is scanned by the electron beam on the screen. The hue is controlled by the intensity of each color in the pixel group. The color intensity is controlled by modulating each of the electron beams in proportion to the color intensity required to generate a specific hue.

The raster scan display technique has advantages and disadvantages that relate directly to the physics of the color generation and screen write process. The advantages of raster scan displays include: (1) multi-color capability, (2) standard television format capability, (3) modulated brightness (blinking and other effects), and (4) low price versus display capability.

When the raster scan display technique is used for data display purposes, the information to be displayed is stored in screen refresh memory. The memory overhead required to refresh the screen can be large. Recall that the electron beam in a black and white raster scan display sweeps from top left to right, line after line, until the bottom right hand corner of the screen is reached, and the cycle begins again. When data are being displayed using a raster scan format, one bit of memory must be assigned to each individual pixel to be displayed for the most simple display where a logic 1 represents a full white and a logic 0 represents black. Thus, a display capable of displaying a 512 by 512 pixel field will require 262,144 bits of memory. If this memory is packaged in 8 bit bytes, 32,768 bytes will be required to represent a binary pixel state (or or off).

If three basic colors are to be displayed, the memory overhead is 786,432 bits (98,304 bytes) because the memory requirement is three times greater than the simple black and white case. In practice, a moderately priced display may utilize a 512 x 512 bit memory plane associated with each basic color. Unfortunately, this screen refresh scheme allows a limited number of hues to be assigned to any pixel on the screen.

A true color display is capable of providing a variety of hues, and this requires that the intensity of each of the three basic colors be controlled. Sixteen levels of hue control capability, for example, will require four bits of memory per pixel. Thus, a display capable of providing 512 x 512 lines of resolution and 16 levels of hue control for each color electron gun will require 3,145,728 bits of memory, or 393,216 bytes if the memory is organized around an 8 byte memory architecture.

The current drawn by the display to maintain this memory overhead is dependent on the type of logic used in the display memory. Both low and high current memories are available. The trade-off is the speed at which the memory operates. Low current memory is slower than higher current memory. Heat dissipation associated with high current memory may also be a limiting factor and a disadvantage depending on user application.

The physics relating to writing any image on a cathode ray tube (CRT) can be a disadvantage depending on display application. For example, if a flat screen is required, the CRT display would not meet the requirements due to depth of the CRT. The CRT may not be optimum in high light level situations. A high ambient light condition could wash the screen.

4.6.7 SUMMARY

Five display technologies have been reviewed. Each is a potential candidate technology for inclusion in the final version netted radar system. The advantages and disadvantages of each technology have been presented. Final system requirements will drive the selection of a display technology and the actual hardware system that incorporates the selected technology.

SECTION 5
SUMMARY AND RECOMMENDATIONS

5.1 SUMMARY

The study reported herein has attempted to determine methods for combining physical security sensors currently under development into a single command, communication, and display system to greatly enhance the usefulness of each independent sensor, provide improved intruder detection, and reduce nuisance alarms. Experience gained during previous programs involving the netting of sensors and the development of automatic detection systems was drawn on to formulate concepts for netting several of the sensor systems currently under development into a single communications and display system. A workable system configuration has been identified; previous netting work provides assurance of low technical risks. In addition, interface concepts for the primary sensors currently under development have been formulated and are presented in Appendix B. A specific interface design for the AN/PPS-15(B) radar is presented in Appendix D. Note that these interface concepts are certainly not the only schemes that could be developed for netting these sensors to a central system, but they do represent a workable scheme which incorporates a great deal of flexibility for the addition of future more capable sensors.

The proposed system which is discussed here is merely the framework for the needed system; more of the details must be filled in prior to implementation of such a system in hardware. Such details should include specific requirements for the performance of the hardware and the specific algorithms to be utilized for processing. (A brief overview of the digital processor requirement is presented in Appendix E.) Previous experience has indicated that nuisance alarms are the primary performance problem area for most automatic sensor systems. Algorithms which take advantage of data available from multiple sensors to reduce nuisance alarms must be developed and evaluated. This study has shown that multiple sensors can be netted into a central display system in a logical manner, but the usefulness of such a netted system to solve the major physical security problems remains to be demonstrated completely.

5.2 RECOMMENDATIONS

A demonstration of a netted system study should be conducted to answer questions concerning the utility of netted systems. This demonstration should be conducted using existing sensors, digital processing equipment, and display hardware in order to save time and money. Such equipment is available from the WIDS, LARIAT, and FIDS programs. This prototype system should be installed at an operational base such as Eglin AFB and used as a research tool to develop better intrusion detection algorithms and ascertain the usefulness of the netted system concept in solving realistic physical security problems. Once the usefulness of the concept is proven, development of an Advanced Development Model using state-of-the-art technology would be the logical next step. In addition, suitable interface design should be factored into sensors currently under development so that they can be utilized as a part of a future netted system.

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APPENDIX A

SENSOR SYSTEM DESCRIPTIONS

A.1 FOLPEN RADAR

A.1.1 SYSTEM DESCRIPTION

This summary description of the FOLPEN (Foliage Penetration) radar system was prepared in support of the Georgia Tech netted surveillance concept investigation. At the time of this research, a written description of the FOLPEN was not available. This system description was assembled after a visit to the Program Manager's Office at the Naval Weapons Center in December 1981. Appreciation is expressed for the help of Mr. John Campell (Program Manager) and Mr. Don Quist (engineer in charge of design). This system description was constructed as accurately as possible from notes made during this visit.

An Advanced Design Model (ADM) of the FOLPEN system was in the design and construction phase at the time of the Georgia Tech visit to the Naval Weapons Center. This ADM was aimed at meeting the USAF requirements. Another ADM was to specifically address the USMC requirements and should have smaller volume, less weight, and longer battery life. The first ADM was scheduled to begin field tests in February 1982.

The FOLPEN radar is a 435 MHz system with a designed maximum operating range of 1500 meters. It is intended to detect a walking man obscured by as much as 300 meters of dense foliage. The Experimental Demonstration Model achieved penetration depths of 245 meters in heavy foliage. The transmitter, receiver, and signal processor are located with the antenna system. The transmitter antenna consists of an array of two dipole corner reflector elements located one above the other. This gives a vertical beamwidth of approximately 20 degrees and a horizontal beamwidth of approximately 120 degrees. The receiving antenna consists of three arrays identical to the transmitter antenna arrays; the center array is directed along the transmitter array axis. The two remaining receiving antenna arrays are aimed 60 degrees to either side of the transmitter array center-line. Monopulse processing between the independent receiver channels allows an azimuth resolution of about 10 degrees to be achieved.

The FOLPEN radar concept has been under development for several years. Figure A-1 outlines the development of this concept and the design goals associated with each development stage. Figure A-2 illustrates the basic block diagram of the radar system.

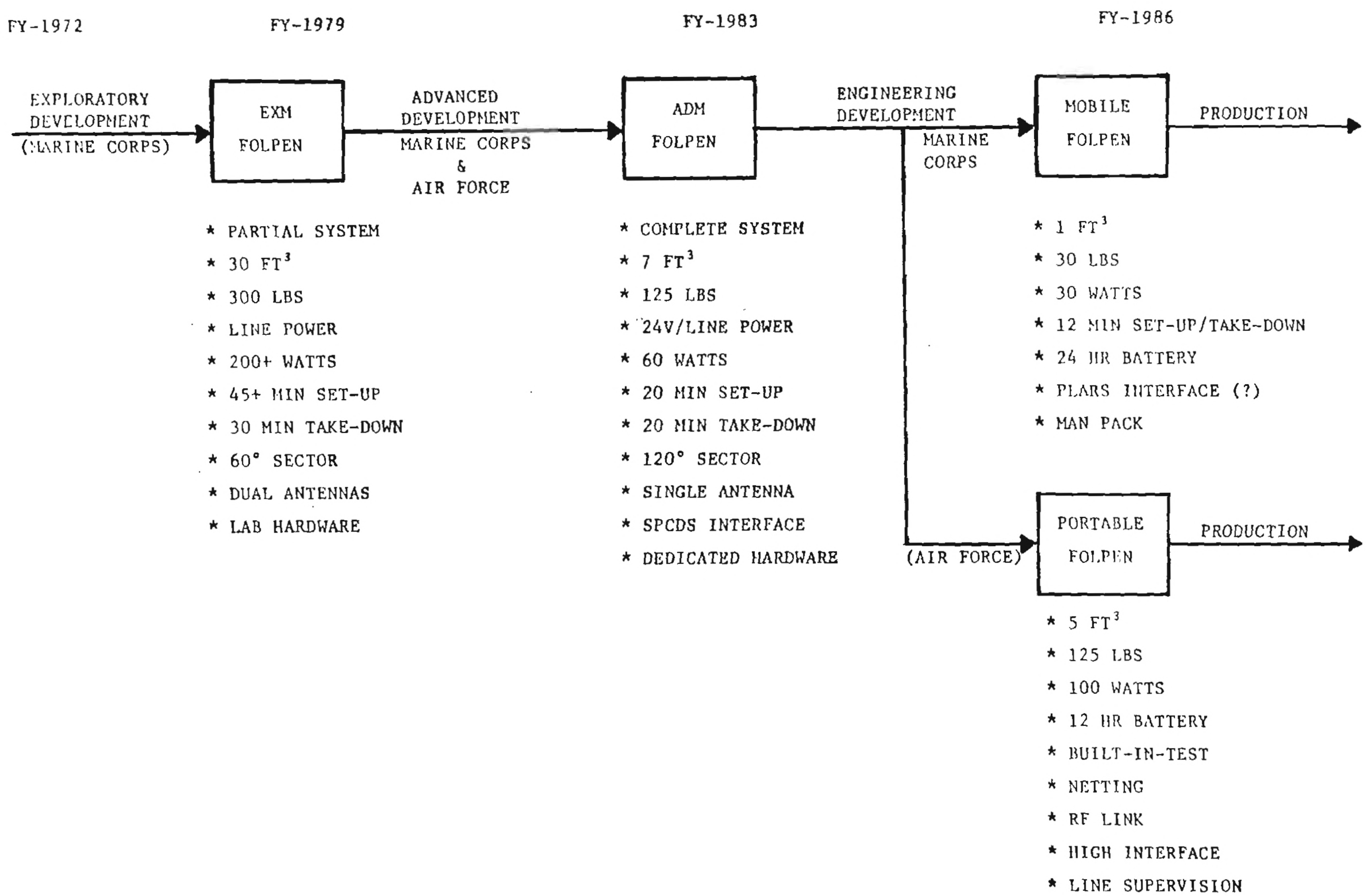


Figure A-1. Development goals for the FOLPEN radar.

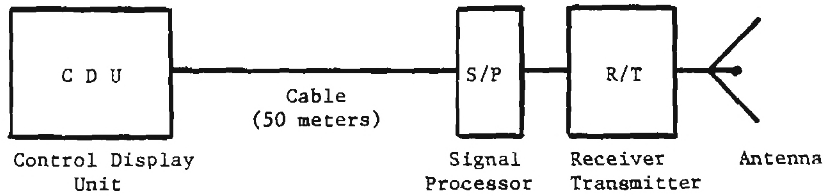


Figure A-2. Block diagram of FOLPEN radar.

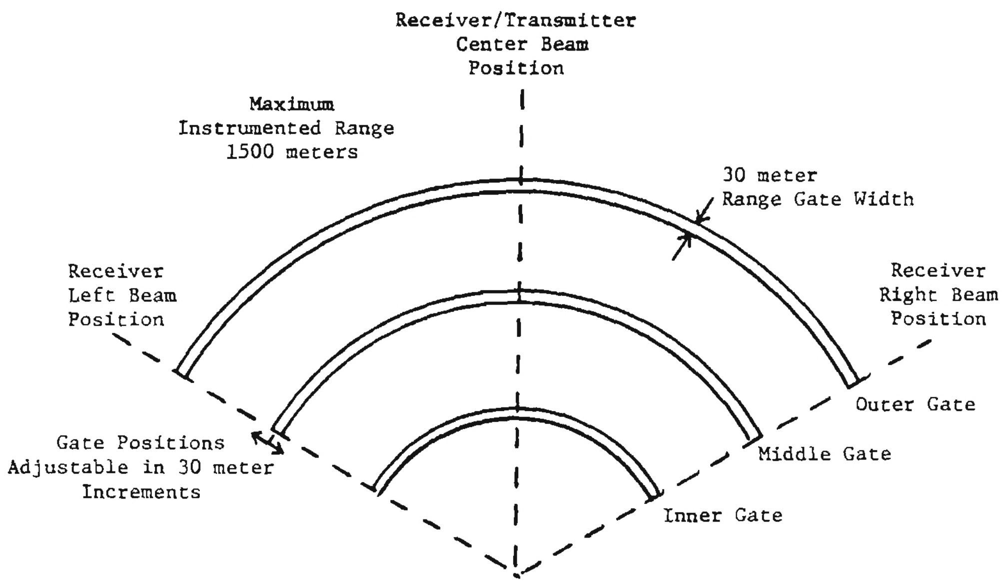


Figure A-3. Diagram showing antenna coverage and range gate definition.

The unit is physically divided into two units to allow the operator to use the control display unit (CDU) from a remote, protected location. The radar receiver/transmitter and the signal processor are located with the antenna system. The antenna units are currently a bistatic assembly that mount on tripod fixtures.

The CDU is the operator interface to the radar system. It provides the operator with a B-scope display and is connected to the radar via a 50 meter cable. The surveillance coverage of the radar is from a minimum detection range of 60 to 90 meters to a maximum instrumented detection range of 1500 meters. Detection of targets having a radar cross section (RCS) of 0.1 to 0.5 square meters can be accomplished at the maximum range for clear terrain. The operator can control three range gates that are 30 meters wide. The inner, middle, and outer range gates may be positioned independently in 30 meter increments (see Figure A-3). Each range gate acts as an electronic fence to detect and alarm on intruders within the gate area. The signal processing system is expandable in concept to accommodate a total of 10 range gates.

The transmitter operates at a nominal frequency of 435 MHz. The radar is a CW Doppler system that operates with a 50 percent duty cycle on the transmitted waveform with a transmitter power of 20 watts peak (10 watts average). The radar transmits a single beam covering the 120 degree surveillance sector.

The radar receiver contains three separate receiver channels that operate independently from three receiving antennas that are positioned with individual boresights separated by 60 degrees to cover the 120 degree field of surveillance. A general block diagram of the receiver is shown in Figure A-4. Each receiver consists of a tuned amplifier having a 50 MHz bandwidth around the 435 MHz center frequency. The tuned amplifier receiver is followed by a correlation processor that decodes the reflected returns and generates a separate in-phase (I) and quadrature (Q) channel for each range gate position (three in the current ADM design). Each I and Q processor has a net gain of approximately 100 dB. The I and Q signals are processed by a baseband and IF section with a half-power bandwidth of 60 Hz. This functional block has a variable gain capability and processes a total of 18 separate channels of data (three range bins from each of the three receivers).

The I and Q signals are time-division multiplexed into a 12-bit analog-to-digital converter. Moving target indicator (MTI) signal processing of the radar targets is accomplished by performing a spectrum analysis on each range bin of each receiver channel using a digital Fourier transform. The spectral results are used to detect targets within the range bin. Each spectral output is divided into 12 frequency bins that are

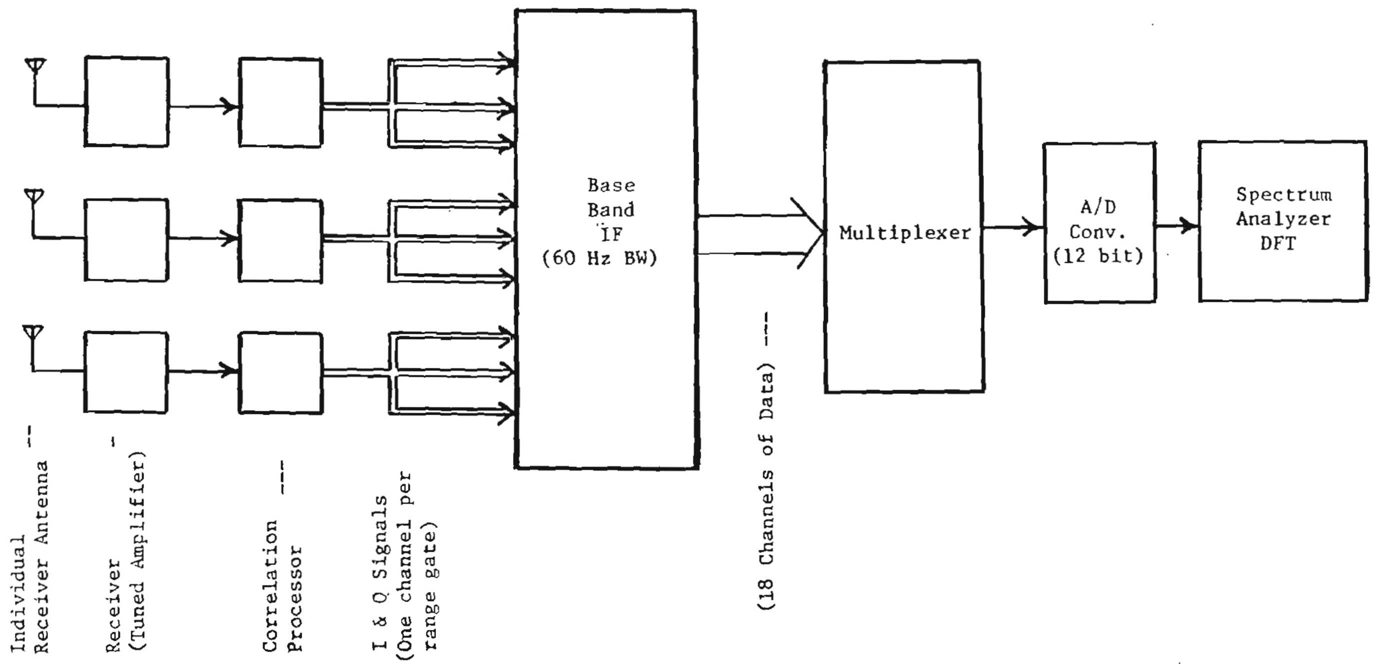


Figure A-4. Block diagram of FOLPEN radar receiver.

logarithmically spaced between 0.58 Hertz and 58 Hertz. The target Doppler frequency bins correspond to a minimum radial velocity of 0.2 meters per second and a maximum radial velocity of 20 meters per second. The spectrum processing time requires 6.5 to 10 seconds, depending upon the velocity of the filters being analyzed.

The FOLPEN radar apparently does not include any form of CFAR as commonly used in radar systems. A variable threshold is set by the ratio of the I and Q signals for each range bin. This threshold is applied to each of the 12 velocity bins of each range gate. The signal processor may specify multiple targets per range bin, giving a target reporting rate of 12 targets per gate (for all three receiver channels).

Each detection report from the signal processor includes information for range, velocity, direction of radial movement (in/out), and receiver beam number. A simple monopulse algorithm is used to determine the azimuth position of the target.

A.1.2 COMMUNICATION FORMAT

The present FOLPEN radar ADM design does not have provisions for external communications or control. The cable interface between the radar and the CDU is a possible access point since the data is formatted into a digital message for the display unit. A maximum target rate of 90 target reports per second is accommodated in the current design. The targets sent to the CDU contain the information shown in Table A-1. This target message is transmitted in serial format consisting of 9 bits of target information and 2 stop bits. The digital target report is transmitted to the CDU by pulse width modulation with a 1 millisecond bit rate.

TABLE A-1. FOLPEN TARGET MESSAGE

1. Range gate number - 2 bit resolution
2. Target speed - 1 bit resolution
3. Target direction (In/Out) -2 bit resolution
4. Azimuth - 4 bit resolution

Control messages are sent to the radar from the CDU only when there is a command to change a range gate position. The command word is a 24 bit serial format plus 2 stop bits that is clocked to the radar at a bit rate of 1 kilohertz. Each range bin position may be specified in any of 50 possible positions (0 through 49) requiring 8 bits of the command word. The total of 24 bits in the command word is to allow the position code for the three separate range bins to be simultaneously transmitted to the radar receiver/transmitter.

A.1.3 NETTING INTERFACE REQUIREMENTS

The FOLPEN radar system concept appears to be an ideal surveillance/ sensor unit for inclusion in a netted sensor system. It provides a surveillance capability in heavy foliage that cannot be met with radar systems operating at significantly higher frequencies.

The ADM radar design appears to be accessible at the interconnection point between the radar and the CDU. The communication rates and data formats described above will be considered in the netting study and definition. In reality, a different communication format and a dedicated interface (input-output port) may be required for operating the ADM in a netted surveillance system.

A.2 EPSD SECTOR SURVEILLANCE RADAR SYSTEM (AN/PPS-15)

This summary description of the AN/PPS-15(B) radar and the proposed product improvement program for the Exterior Perimeter Surveillance Device (EPSD) was prepared in support of the Georgia Tech netted radar-fixed sensor surveillance system concept study. The AN/PPS-15(B) does not currently exist in a form that is directly applicable to the netted radar surveillance system. The proposed EPSD is scheduled to include a capability for interfacing with other systems. Since the EPSD is proposed as a product improvement to the AN/PPS-15(B) radar, the two summary descriptions were combined into this single description.

The AN/PPS-15(B) radar is a solid-state very short range ground surveillance radar. It operates at X-band frequencies and is limited to line-of-sight operation. The radar can detect, locate, and recognize fast and slowly moving vehicles and personnel under varying conditions of terrain visibility and weather. The radar set provides both audible and visual alarm indications of targets, and provides a digital readout of range and azimuth to the target.

The radar system produces a phase modulated waveform out of the transmitter, and the radar receiver uses the reflected waveform to generate the characteristic Doppler frequencies of moving targets within the audio range (between 15 and 1350 Hertz) for targets moving at radial speeds between 0.5 and 45 miles per hour. These Doppler frequencies are amplified and used for audible detection of targets in the operator's headset and a tone of the alarm speaker. Target detection is also visually provided as a blinking alarm indication. A summary of the general operating parameters is presented in Table A-2.

The AN/PPS-15 radar will provide surveillance of moving ground targets within the illuminating beamwidth of the antenna (approximately 5.6 degrees). The radar is provided with a tripod base assembly that allows either manual or electrical rotation of the radar set. Increased sector coverage is obtained by electrically rotating the radar/antenna system in a sector scan mode by means of an electrical motor in the tripod mount. The scan sector is variable between sector widths of 22.5 degrees and 180 degrees. The scan rate is approximately 90 mils (5.1 degrees) per second.

Target detection occurs when a moving object produces an audible sound in the operator's headset and an audible and visual alarm from the automatic alarm circuits within the radar set. A block diagram of the AN/PPS-15(B) control unit is given in Figure A-5. Once a target has been detected by the operator, the radar set typically is used to track the target. Target tracking is accomplished by changing the antenna azimuth and elevation and the RANGE (i.e., the position of a range-gate) control to maintain maximum volume tone in the headset and a maximum number of dots on the PEAKING indicator. While tracking individual targets can provide information about the direction, location, and speed of the target, it requires a one-on-one situation between an operator and the target. This is different from the approach taken in the netted radar-fixed sensor surveillance system. In this application, the approach is to maximize the data available to a single operator and to automate as many of the detection-tracking functions as practical.

The process of target detection in the AN/PPS-15(B) is assisted through the use of 7 range gates that are prepositioned by the radar operator. A block diagram of this signal processing and range gating circuit is illustrated in Figure A-6. These range gates can be set to trigger the alarm modes available to the operator for an intrusion into any one of the gates, or the output from all of the range gates can be combined to respond to a target in any one of them. The range bins can be positioned to provide continuous coverage, or they can be separated with equal spaces between adjacent range bins. This radar has a location accuracy of approximately plus or minus 40 meters in range and plus or minus 20 mils in azimuth.

The AN/PPS-15 radar currently does not have a capability for interfacing to a remote netting facility. A suitable interface must be developed to allow remote operation of the radar via a command link for setting the operating parameters of the radar and a data link for receiving the target data from the radar receiver. To be most

TABLE A-2. TYPICAL OPERATING PARAMETERS OF AN/PPS-15 RADAR

a. General.

Range:	
Personnel: Walking or running (0.5 square meter target)	50 to 1,500 meters (55 to 1,640 yards).
Crawling (0.05 square meter target)	50 to 500 meters (55 to 547 yards).
Vehicle (10 square meter target)	50 to 3,000 meters (55 to 3,281 yards).
Determination	Numeric electronic readout indicators coincident with aural indication and visual presentation on the range PEAKING indicator on the control indicator.
Accuracy	±20 meters (±22 yards).
Target velocity	0.805 to 56.326 kilometers per hr (radial) (0.5 to 45 mph (radial)).
Resolution	35 meters (38.3 yards).
Azimuth:	
Coverage	± 4800 mils (± 270°) manual
Determination	Numeric electronic readout on control indicator
Automatic sector scan width	400 to 3200 mils (22½° to 180°) continuously variable.
Scan Center	Can be set to any desired azimuth 3200 mils left or right of center
Accuracy	±10 mils (±0.6°).
Scan rate	90 mils/sec ±9 mils.
Resolution	100 mils (5.65°).
Elevation:	
Coverage (manual tilt)	Not less than +400 to −600 mils (+22.5° to −33.75°) manual.
Determination	Calibrated elevation scale on antenna drive.
Assembly time	One person in less than 10 minutes from transport case to tripod configuration

b. Transmitting System.

Frequency	10.3 GHz Nominal.
Tuning range (Electronic)	± 20 MHz about 10.217 to 10.383 GHz
Tuning range (Mechanical)	10.197 GHz to 10.403 GHz.
Radiated power	30 to 94 milliwatts; 45 milliwatts nominal average power.
Stability, frequency	1 part in 1000 parts from set point.
Modulation	Fm/cw.
Source of rf power	Gunn oscillator.

c. Antenna System.

Radiating element	Vertically polarized slot array.
Antenna gain	27.5 db.
Horizontal beamwidth	100 mils (5.6°) nominal
Vertical beamwidth	177.7 mils (10.0°) maximum.
Side lobe level, relative to main lobe:	
Azimuth plane	−14 db.
Elevation plane	−13 db.

d. Receiving System.

Type	Homodyne.
Mixer	Hot-carrier diode, type HP5082-2751.
Sensitivity	0.5-square meter (0.598 square yard) target at 1,500 meters (1,640 yards).
Noise figure:	
Search mode	Not more than 12 db.
Range mode	Not more than 10 db.
Aural presentation	Headset provides audio doppler tones for target detection location and identification.

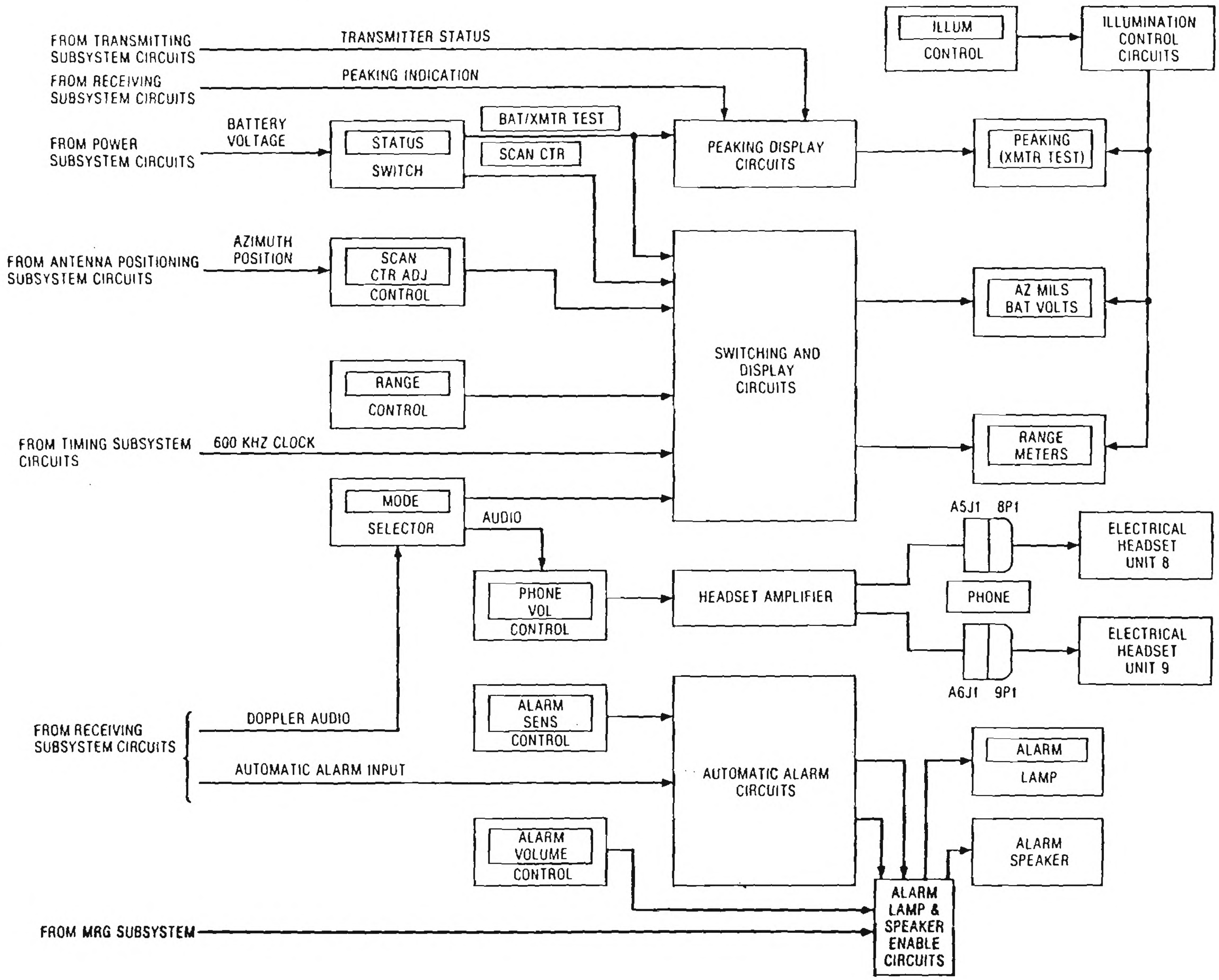


Figure A-5. Block diagram of AN/PPS-15(B) control unit.

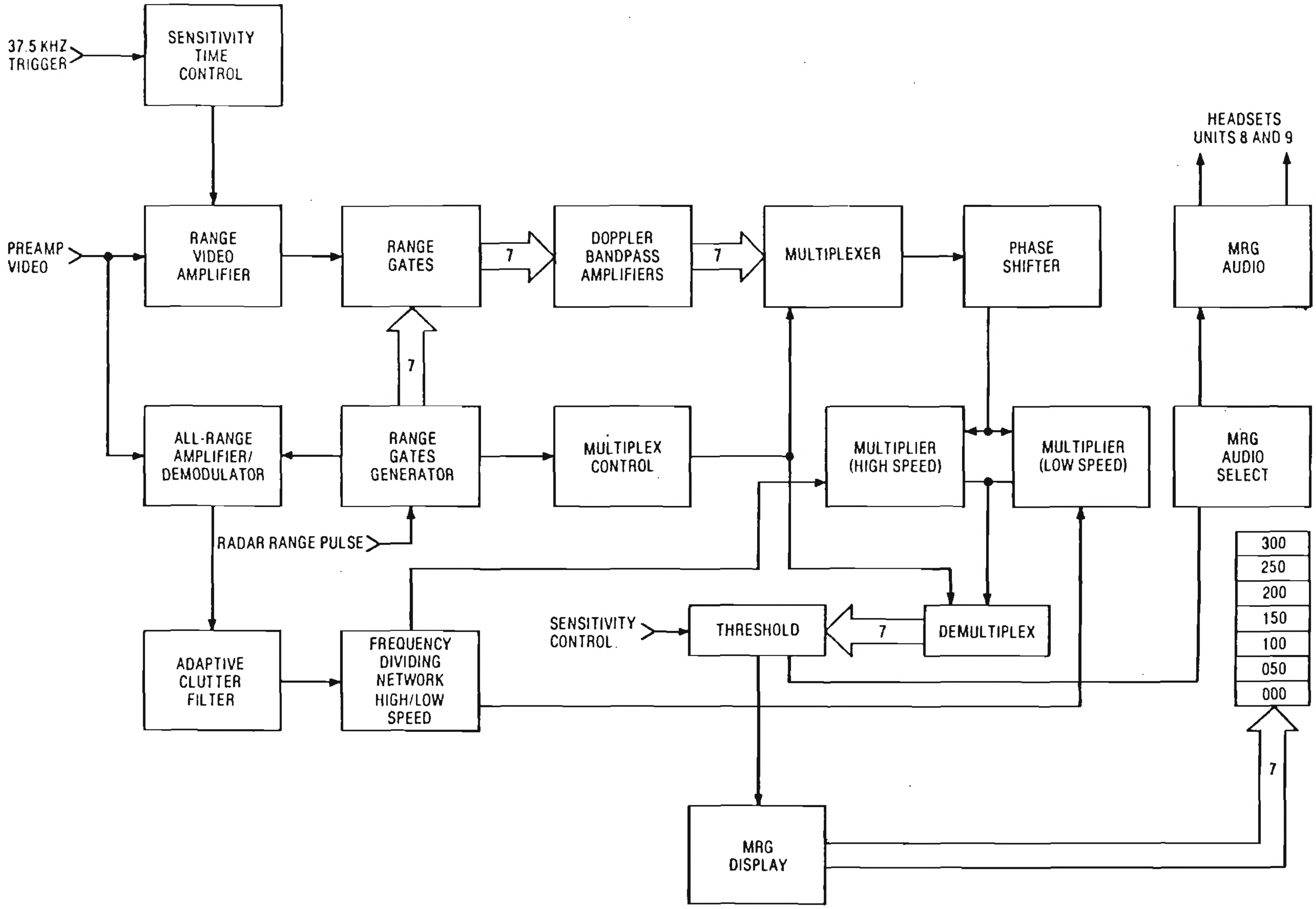


Figure A-6. Block diagram of signal processing section of AN/PPS -15(B).

effective, the radar system must be used in a track-while-scan mode. This will require additional algorithms for detecting and reporting targets when the radar set is connected into a netted surveillance system.

A product improvement program has been proposed for the AN/PPS-15(B) by General Dynamics. The improved system design is designated the EPSD and is intended to affect the Operator Control Indicator Unit only. It is currently proposed that an input/output (I/O) interface will be part of the improved system. The improved system will also include a capability for automatic range/azimuth target tracking, an extension of the non-ambiguous range to 6 kilometers, and a capability for random scan width and scan speed. A comparison of the AN/PPS-15 and the EPSD improvements is given in Table A-3.

This short range sector surveillance radar will be a very valuable sensor to the netted radar-fixed sensor surveillance system. However, it can not be used efficiently in its current form or in the EPSD form proposed for the product improvement program. The addition of an interface data link to the surveillance radar must include several functions outlined in other sections of this report if an efficient interface with the netting system is to be achieved. The radar system must also operate in a true track-while-scan mode to allow the netting computer to automatically detect and track on a number of targets simultaneously within the sector of coverage.

A.3 LARIAT SYSTEM

A.3.1 OVERVIEW

This system summary describes a netted ground surveillance radar system that was designed and field tested at the Yuma Proving Ground in 1978. The system known as the Long Range Area Radar for Intrusion detection And Tracking (LARIAT) System was developed in support of the MX-missile base security program and was supported by the US Air Force Space and Missile Systems Office (SAMSO) - now the Ballistic Missile Office (BMO). This system concept is very relevant to the current netting study since it was used to prove the effectiveness of many of the radar tracking algorithms discussed in this final technical report. The area surveillance radars used in the LARIAT system are also considered to have many of the performance requirements necessary for a wide area radar surveillance system. Therefore, this summary description has been prepared as reference material for the Georgia Tech concept investigations of netted radar-fixed sensor surveillance systems.

TABLE A-3. EPSD SUMMARY OF SYSTEM REQUIREMENTS
AN/PPS-15(B) VERSUS AN/PPS-15( ) PIP-1

		AN/PPS-15(B)	AN/PPS-15( ) PIP-1
o	Weights		
	Operational	35	25
	System	150	140
o	Range (Detection 80% PD, Single Scan)		
	Man - Walking (0.5 m^2)	1500 Meters	Same
	Vehicle - Jeep	3000 Meters	Same
	Armor - Van (20.0 m^2)	N/A	4000 Meters
o	Target Tracking		
	Range/Azimuth	Manual	Automatic
o	Accuracy	Same	Same
o	Resolution	Same	Same
o	Prime Power		
	Battery	NI-CAD (External)	NI-CAD (Internal)
	External Power AC	115/220 VAC	Same
	External Power DC	24 VDC Vehicle	Same +12 VDC Vehicle
o	Scan Driver	Brush-Type DC PM Motor	Brushless DC PM Motor
	Preset Scan Times	Random Scan Times	
o	Netting Compatibility	No	Yes

The increasing importance of security for nuclear materials and weapons demands a reliable and cost effective solution for the security surveillance of the very large base areas needed for the missile (MX) system. Such a surveillance system must possess a very high probability of detection with a low false alarm or false dispatch rate. The MX basing scenario requires the surveillance and tracking of threat and non-threat intruders over large base areas located in undeveloped regions of the continental United States, such as the desert regions of the southwest.

Personnel detection radar technology could be a cost effective surveillance approach for monitoring and protecting these large base areas. The sizes of these proposed bases are sufficiently large to require surveillance by several such radar sensors to accomplish the desired detection probability and reduce the effects of terrain masking. The use of multiple radars for detecting, tracking, and identifying threat targets requires a large number of operators or a sophisticated data processing/handling system. This weapon system will have an expected operational life of several years, and the cost of personnel for security protection becomes a significant cost driver in the overall system design. For this reason, the automatic control of the radar systems and the functions of detection, tracking, and operator alarm were approached through a central computer/signal processing system to net the radar surveillance sensors into a common operator machine interface. This interface provides the operator with track information for the entire base area in the form of a situation map that can be used to vector security forces to intercept threat target tracks or identify targets of unknown origin.

The MX deployment scenario requires routine deployment of security patrols and maintenance personnel within the protected base area. These friendly personnel must be easily recognizable by the surveillance system to reduce the workload on the data processor and the monitoring operator. This requires a parallel capability in the intrusion detection system that can detect and track Identification Friend or Foe (IFF) transponder units carried by these friendly forces. This transponder tracking system parallels the signal processing of skin returns from the moving personnel and allows the operator Alarm functions to be bypassed for defined non-threat tracks.

This appendix summarizes the development and field testing of a netted radar surveillance system concept for protecting a large base area such as described above. This feasibility demonstration program was designated the LARIAT security system. The surveillance concept was developed for the MX program office of the U.S. Air Force Space And Missile System Organization (SAMSO). LARIAT was designed to provide a dependable surveillance system for the MX basing scenario that required minimal operator attention until threats or potential threats within a defined base area were automatically detected according to prescribed threat algorithms. The system approach also met the requirement for identifying friendly forces via a transponder IFF system. The surveillance devices were modified AN/PPS-5 personnel detection radar sets manufactured and supplied by the AIL Division of Cutler-Hammer Group, Eaton Corporation. The associated remote command/microwave data link system and the radar system interface were also supplied by AIL. The Georgia Institute of Technology Engineering Experiment Station (GIT/EES) developed the data processing/display portion of this feasibility demonstration system, along with all computer/signal processing algorithms, under contract with the CS&TA Laboratory of the U.S. Army Electronics Research and Development Command (ERADCOM), Ft. Monmouth, New Jersey (Contract DAAB07-77-C-2147), who provided technical advice and administration. The radar system and data link system were supplied and supported by AIL under a separate ERADCOM contract (Contract DAAB07-77-C-2138).

A.3.2 BACKGROUND

Radars operating in a netted configuration were chosen as the surveillance sensors for the LARIAT system since the technology of personnel detection is well-proven and suitable radar designs that required only moderate modifications were available. This surveillance approach can potentially provide multiple coverage of both ground targets and low flying aircraft in an economic manner. It can meet the design goals for an automatic tracking system for both unknown (or threat) intruders, as well as friendly personnel and maintenance forces. The research effort addressed three separate problem areas related to this surveillance system concept.

The first area involved the design, development, and testing of a feasibility demonstration of the LARIAT computer netted radar surveillance system concept. This concept is illustrated pictorially in Figure A-7. The tower mounted radar sensors provide overlapping coverage of both friendly and unfriendly targets within the base area. Friendly targets give both a skin return and an IFF transponder return that are processed separately to inhibit the operator alarm functions for these non-threat targets. This feasibility demonstration was made using two radars, but all other software and hardware parameters were conceptually expandable to ten such sensors.

The design philosophy for the LARIAT system was to provide an automatic surveillance system that does not require constant monitoring by an operator. The

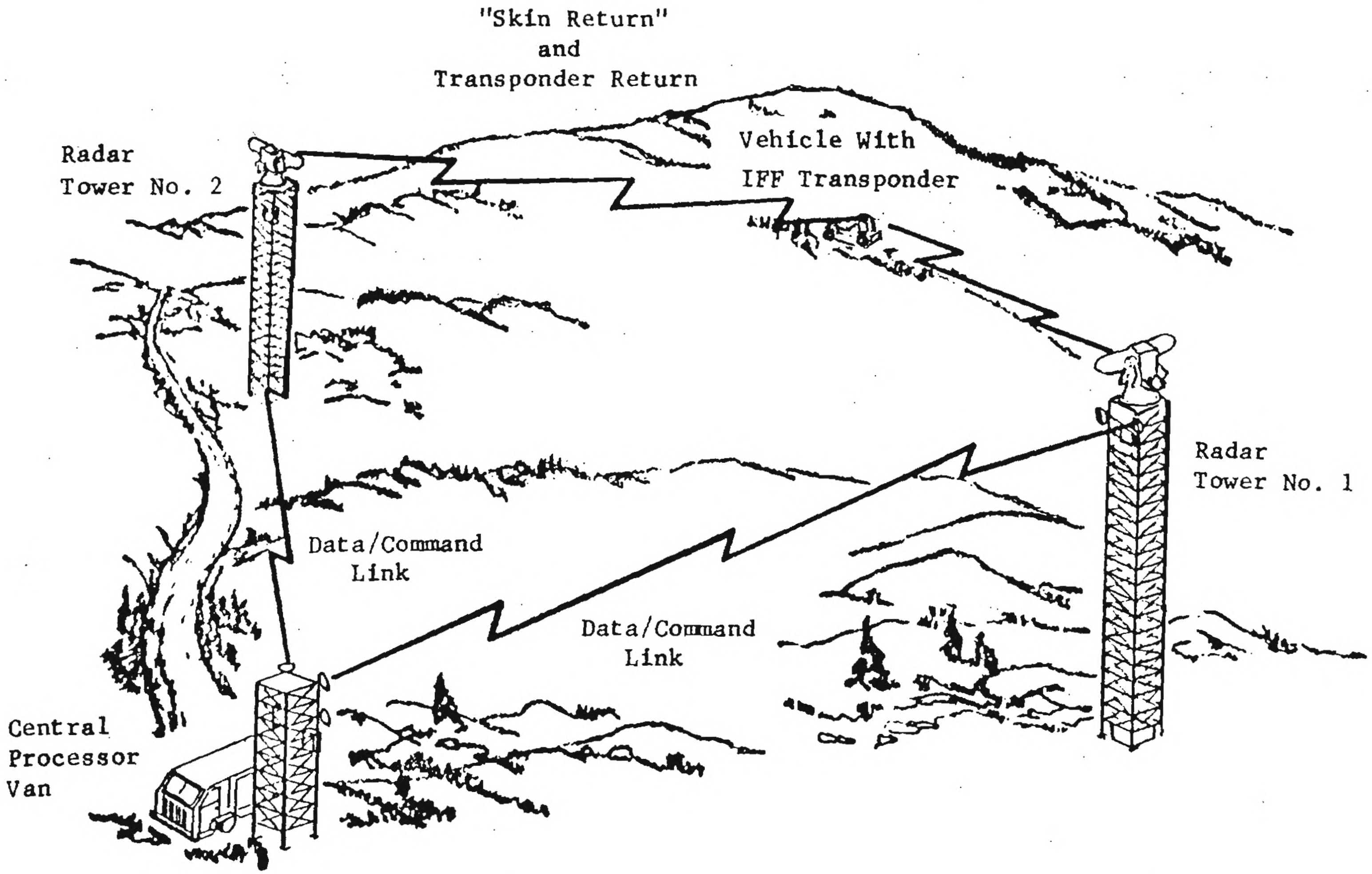


Figure A-7. Illustration of LARIAT concept for feasibility demonstration.

LARIAT system was designed to automatically detect and track ground targets (such as a walking man, a man riding a horse or a motorcycle, vehicles) and low-flying aircraft, and to alert the operator only when prescribed threat conditions were met. The system has the capability of simultaneously interrogating and tracking several IFF beacon transponders to aid the operator in identifying friendly target tracks. All radar information and recent track histories are presented to the operator in a situation map format on a computer graphics display system. The central computer facility controls the radar systems, processes target data from all radars, performs track analysis, and controls the operator display system.

The goals for the LARIAT system feasibility demonstration may be summarized as:

1. Provide wide area surveillance with high probability of detection with low system false alarms or false dispatch rate,
2. Correlate the outputs of several radars into a common data processor and display,
3. Provide automatic detection and track,
4. Provide automatic track assessment,
5. Integrate IFF capabilities,
6. Provide effective man/machine interface enabling rapid reaction time by:
    a. Combining radar information with computer graphics on a common status map display,
    b. Providing a time compressed display of the radar data to enhance the visual recognition of movement patterns,
    c. Integrating the IFF responses (position and identity) into the map display,
    d. Storing recent target files for system recall, and
    e. Providing an interactive control/display interface between the operator and the computer/display systems,
7. Operate the LARIAT system in desert terrain typical of an MX installation and evaluate performance, and
8. Define the system parameters of an operational system.

The field tests of this system were performed at the Yuma Proving Ground during the summer and fall of 1978. Operation of the system in its design configuration was demonstrated. Its performance against a test matrix of threat targets was demonstrated during this test period. The data base established during these tests is valuable in specifying the requirements for an operational system.

The threat targets for this system were considered to be a single man or a group of men walking or riding (horseback, motorcycle, dune buggy, or jeep). Non-threat targets in the desert environment were considered to be animals (such as the coyote, burro, mustang, deer, goat, and birds) and weather phenomena such as dust devils and thunderstorms. The range of velocities for the threat targets considered here varied from less than one-half meter per second to more than 50 meters per second.

A second area of this research involved an investigation into radar concepts to evaluate various system characteristics that would be recommended for an operational surveillance radar system for an extended MX base installation. Another area of this research was directed toward the development of suitable target discrimination algorithms potentially useful for automatic target identification and verification. This work consisted primarily of the measurement of the calibrated radar characteristics of fixed geometrical targets of conductors and non-conductors, and of the dynamic RCS of walking human subjects. The primary goal of these measurement tasks was to supply Dr. Robert Harrison of TRW with information suitable for the verification of his computer modeling of radar targets. These measurements included controlled experiments at UHF, S-band, and X-band on radar measurement ranges located at the GIT/EES campus facilities. The measurement program also included the recording of selected target returns from the AN/PPS-5 radar system during the Yuma Field Test. Selected samples of the data at all four frequencies were provided in a digital computer tape format to Dr. Harrison for his studies. A limited scope analysis was also performed in an attempt to identify target signature features which could be exploited for target discrimination and classification or otherwise influence system design.

A.3.3 LARIAT SYSTEM DEVELOPMENT

The LARIAT system design presented unique challenges in the development of signal processing equipment and algorithms for the automatic detection, tracking, and alarming of suspected intruders in the protected area. The unique problems common to this system included: irregular track sampling intervals, extremely low data rates, and wide variations in the expected velocities and radar cross section of the threat targets. Netting together two to ten scanning radars with various degrees of overlapping coverage increases the data processing requirements by introducing a random period between target detections. The characteristics of the netted radar system used in LARIAT made it difficult to use conventional tracking methods to project a search sector ahead in time to match target detections with known tracks. This was due to the almost random time interval between detections of a given target as it proceeded along its track. This random pattern in the sample interval was related to the overlapping radar coverage of the track and to the options in speed and direction that were applied independently to each radar scan.

The computer analysis of radar signals in real time dictated extremely high performance processing to handle the very high data rate. There was redundant information in the radar returns as seen at the output of the remote data link. Some of this redundancy was introduced by the integration process at the radar receiver-transmitter used to provide bandwidth compression of the signals before transmission over the data link. The data rate at the output of the radar receiver was calculated by observing that each transmitted pulse from the radar was followed by a return signal that was divided in time to correspond to 200 independent range bins (each having 50 meters resolution). These transmitted pulses occurred at a frequency of 2 kHz, providing an information rate of 400,000 range bin samples per second per radar at the input to the MTI processor. These signals were processed independently to detect moving targets for each range bin. The bipolar MTI output signal which indicated the presence of a moving target in a given range bin was rectified and integrated independently for each range bin. The integrator summed the current return with the weighted sum of past returns. The integrator time constant was approximately equal to the interrogation period of the multiplexed data link system. The output of the integrator was then transmitted to the CPU van in data word groups at a 50 Hz multiplexing frame rate to reduce the data rate to only 10,000 range bins per second per radar.

The 200 sequential digital data outputs of the MTI processor/integrator were converted to a pulse amplitude modulated analog signal and transmitted over the data link to the CPU van. At the receiver end of the data link, the signal was converted back to a digital format and organized into a data word package for interfacing to the computer system. The contents of each range bin were represented at this point by an 8-bit binary word. This provided sufficient resolution to cover the received signal dynamic range expected.

The LARIAT surveillance system (as field tested at the Yuma Proving Ground) combined the outputs of two ground surveillance radars (mounted on towers) within a single data processor and display system. The hardware and software design conceptually allows for the expansion of the system to ten such surveillance radars under the control of the central computer facility. The feasibility demonstration used two modified AN/PPS-5 radar sets mounted on 100 foot towers. The towers were located approximately 6.5 kilometers apart allowing overlapping radar coverage on the test area to ensure maximum surveillance by minimizing the effects of terrain masking. The AN/PPS-5 radars were modified by reducing the horizontal beamwidth of the antenna from 1.2 to 0.7 degrees, providing continuous processing of all range bins out to an instrumented range of 10 kilometers, and providing an increased range bin resolution of 50 meters (a total of 200 range bins). The PRF of the transmitter was reduced to 2 kilohertz to eliminate the problems of second time around targets, and the receiver was modified to provide a coherent-on-receive capability. The radar signal preprocessing functions were accomplished using hardwired digital designs.

The hardware and software algorithms for processing and displaying the radar information at the central processing van were developed at GIT/EES. This portion of the system was installed in an air conditioned step van that was interconnected to the remote radar towers by two-way microwave data links. A parallel microwave data link was used for the remote control of the co-boresighted TV cameras mounted on each radar pedestal. The LARIAT system design presented several unique challenges in the development of the signal processing equipment and the development of suitable software algorithms to provide the functions of automatic detection, tracking, and alarming of suspected intruders into the protected base area. Several problems unique to this system include irregular track sampling intervals and extremely low data rate of track information (related to the slow scanning rates for the radar), wide variations in the expected target velocities, and wide variations in the radar cross section of the threat targets.

Slow scan speeds were required for the AN/PPS-5 (modified) radar system to detect slow moving, small targets such as a walking or crawling man. Scan speeds of the LARIAT system fielded in Yuma were remotely controlled through the digital computer. Selectable scan speeds of 18 degrees per second to 2.25 degrees per second corresponded to time periods of 20 seconds through 160 seconds required to cover a 360 degree scan sector. The modified radar antenna employed a 3 dB horizontal beamwidth of 0.7 degrees (approximately 12.4 mils). This beamwidth was interpreted as an independent azimuth sector; thus, there were 514 such individual sectors over each 360 degree scan. The 20 millisecond (or 50 Hz) interrogation period (established by the telemetry system) of each range bin of each radar provided multiple readouts of the return from a target within a given range bin as the antenna pattern swept across the target azimuth position. The number of responses through the multiplexed data link depended on the scan speed. This redundant information was used to great advantage in the data processing algorithms for target detection and verification.

A distributed (both parallel and serial) computing system concept was adopted to handle the large computing load demanded of the central processing system. A block diagram of the basic LARIAT data processing system used for the Yuma feasibility demonstration is illustrated in Figure A-8.

The central computer system used to analyze the combined radar information and to interface with the operator display and other peripherals was a NOVA-3 computer. Preprocessing of the remaining large volume of received radar data prior to the NOVA-3 computer occurred in two levels of high-speed microprocessors specifically designed for this application. The data flow chart in Figure A-9 illustrates the basic data processing operations performed between the radar/computer interface and the operator/display interface of the LARIAT system. The Data Distribution Preprocessor (DDP) unpacked the time division multiplexed data signal from the data link equipment. The microcode program in this preprocessor was completed within the four millisecond period allocated to each radar by the data link system. This included the transmission of the common word package and the receipt of the radar data word package. The complete computer program was repeated for each radar interrogation. The high operating speed of these microprocessors can accommodate a much higher multiplexing rate from the data link with no hardware changes. The important data processing algorithms accommodated in this distributed data processing system included a range only CFAR algorithm for the process of target detection and an M-out-of-N integration algorithm for the function of target verification. These two processes (contained in the microprocessor software) initiated target reports to the NOVA-3 system. The data processing algorithms within this main computer associated the target reports stored on tape and disk files to establish target tracks according to prescribed software requirements. Threat analysis and alarm conditions to the operator were made only on established target tracks.

The principle objective of the LARIAT program was to demonstrate the feasibility of the netted wide area surveillance radar concept in providing physical security for a MX missile installation scenario. The goals supporting this system objective included the development of the necessary hardware and software technology for netting radars of this type. These goals also included the integration of an IFF capability and the demonstration of automatic detection, tracking, and alarming on threat targets. This system was designed to provide an effective man/machine interface for controlling the radars, interpreting track information, and directing friendly or security forces to intercept target tracks of unknown origins. This system concept was field tested in the desert environment of Yuma Proving Ground to answer specific questions on performance and to generate the necessary data base for designing operational systems.

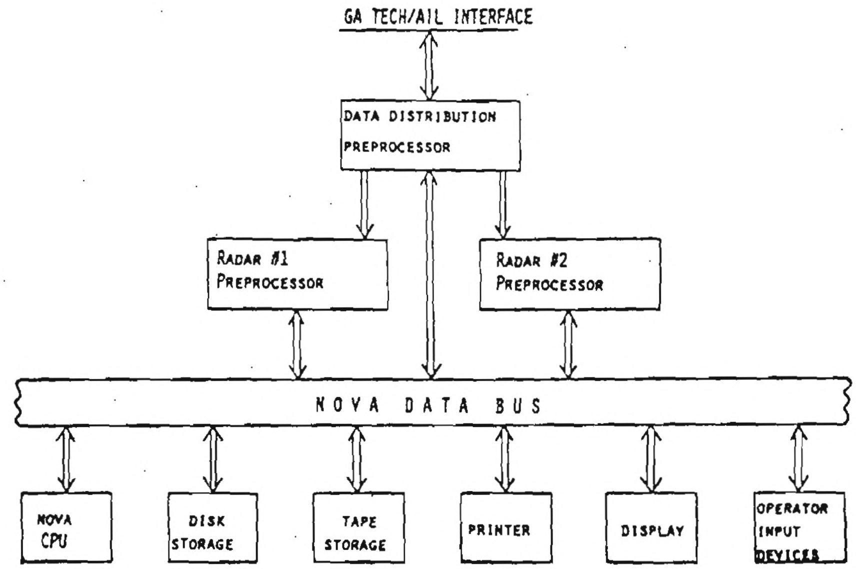


Figure A-8. LARIAT distributed data processing system.

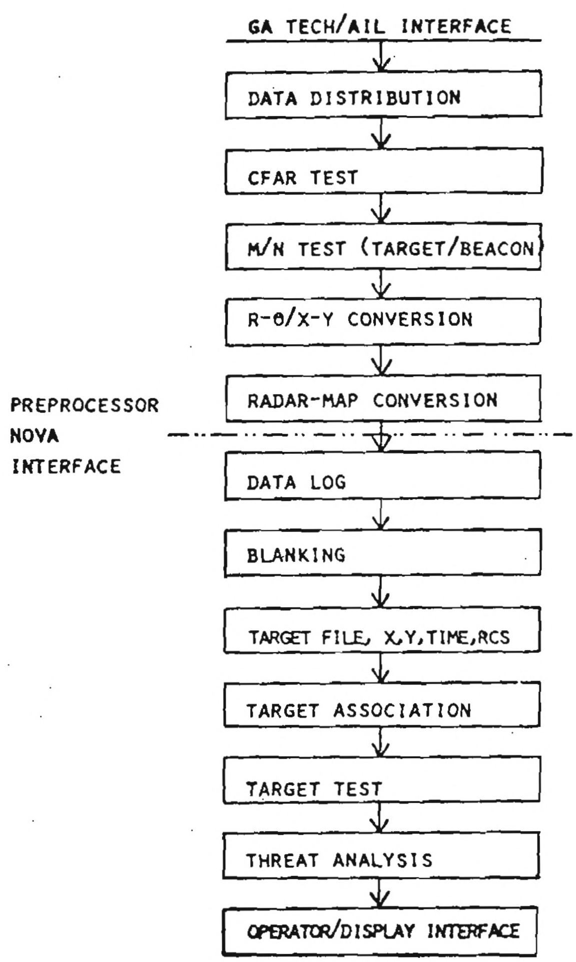


Figure A-9. Data processing order in the Georgia Tech LARIAT system.

A.4 THE FACILITY INTRUSION DETECTION SYSTEM (FIDS) SYSTEM DESCRIPTION

A.4.1 BACKGROUND

The FIDS netted surveillance system is being developed at Ft. Belvoir for the U.S. Army. A comprehensive description of the FIDS system was not available and this summary description was assembled for the Georgia Tech concept study of netted radar-fixed sensor surveillance systems after discussions with Mr. Al Zushin and Mr. Dale Rehak (of Ft. Belvoir) in December of 1981. Copies of briefing material on the FIDS concept and a description of the Interface Specification for the Control Unit/Line Control Processor were obtained during the Georgia Tech visit.

The original FIDS concept (FIDS I) was started in 1974. This system had a single console rack connected to 32 control units. The operator interface to the FIDS I consisted of a printer and a series of light bulbs.

The original unit was superceded by the FIDS II system in 1976. FIDS II had a console connected to 96 control units (each addressing 6 point sensors). The original system was built by Labarage Electronics of Tulsa and included the line control processor architecture that will be used in the upcoming FIDS III system. It also upgraded the operator interface with a random access slide projector that could be used for maps or instructions. This element was later removed by the Ft. Belvoir personnel due to poor reliability. The resulting in-house changes introduced the two CRTs that are used for the status amd map displays. These operator-display interfaces have been retained in the FIDS III design.

The FIDS III prototype system is currently being built by Sylvania at Mountain View. This contract was awarded in December 1978 for 6 complete units. The first prototype model of the FIDS III (scheduled for delivery in the near future) will include the console and a complete complement of 16 line control processors (LCP) and control units. The system will have only 2 sensors per control unit (CU). Development tests are currently scheduled for September 1982. The U.S. Army proponent for the system is the Military Police School. The main point of interest in the U. S. Air Force is the Office of Security Police at Kirkland.

A.4.2 SUMMARY DESCRIPTION

The FIDS system is a fixed installation security and alarm system that allows the operator to interface with a large number of fixed sensors of several different types. The operator display console (see Figure A-10) connects up to 4096 remote sensors to a

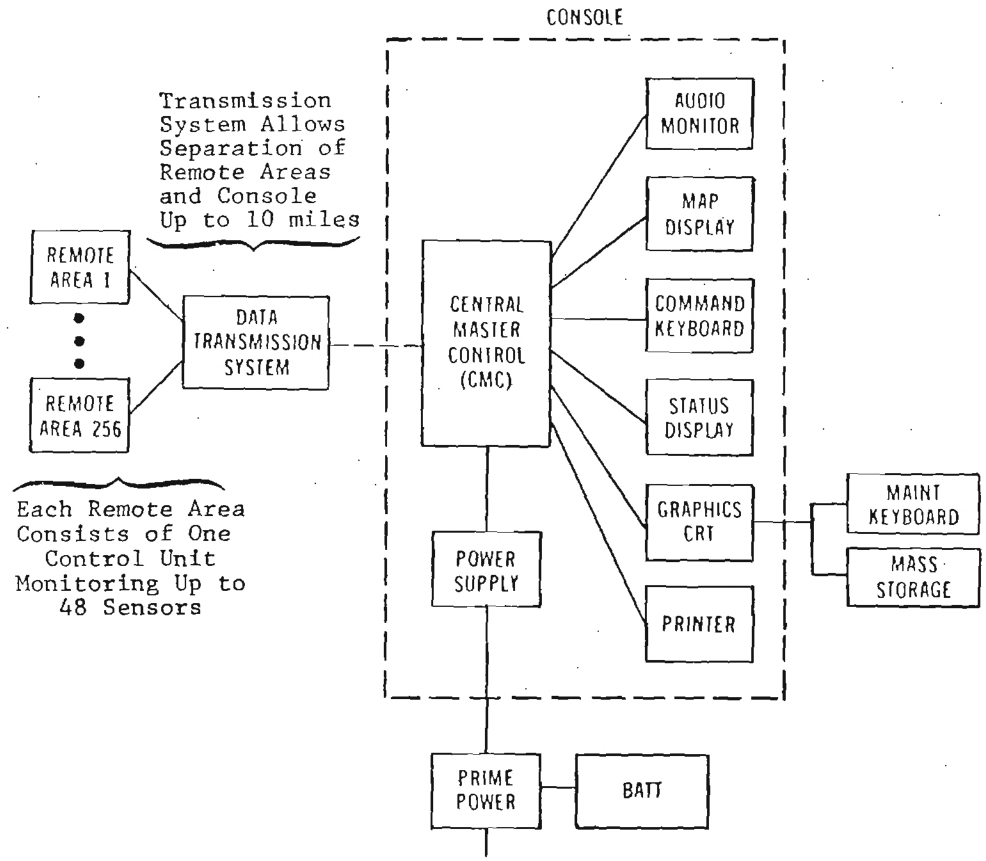


Figure A-10. Block diagram of Facility Intrusion Detection System (FIDS).

common display/alarm system. The console contains the central master control (CMC), the audio monitor for selected acoustical monitoring by the operator, map and status displays, printer, and the command keyboard. The system provides secure and reliable communication between the sensors located in remote secure areas and the display unit. The communication link operates on an interrogate-respond principle which reports configuration and status information from each secure area interconnected to the control/display unit.

A number of different types of sensors may be used with the FIDS system. Table A-4 describes the generic types of sensors and the common application area.

TABLE A-4. SENSORS CURRENTLY COMPATIBLE WITH FIDS

Sensor Type	Area of Application
Ballanced Magnetic	Detects penetration through switch door or window
Passive Ultrasonic	Detects ultrasonic energy generated through forced entry
Vibration	Detects vibrational acceleration forces on wall or fence
Ultrasonic motion	Detects intruder motion in protected volume (12 x 20 x 30 ft)
Passive Infrared Motion	Detects intruder motion Sensor at rates of 0.1 to 15 ft/sec
RF motion sensors	Bistatic area surveillance (approx. 930 m^o) for low velocity targets
Capacitance	Proximity/contact sensor (10 to 40 decks)

The operator console communicates with the sensor in a tree configuration through the line control processor (LCP). Up to 16 of these LCPs may be used in the full scale FIDS system. Each of these LCPs may be connected to a total of 16 control units as illustrated in Figure A-11. This gives a full system capacity of 256 control units.

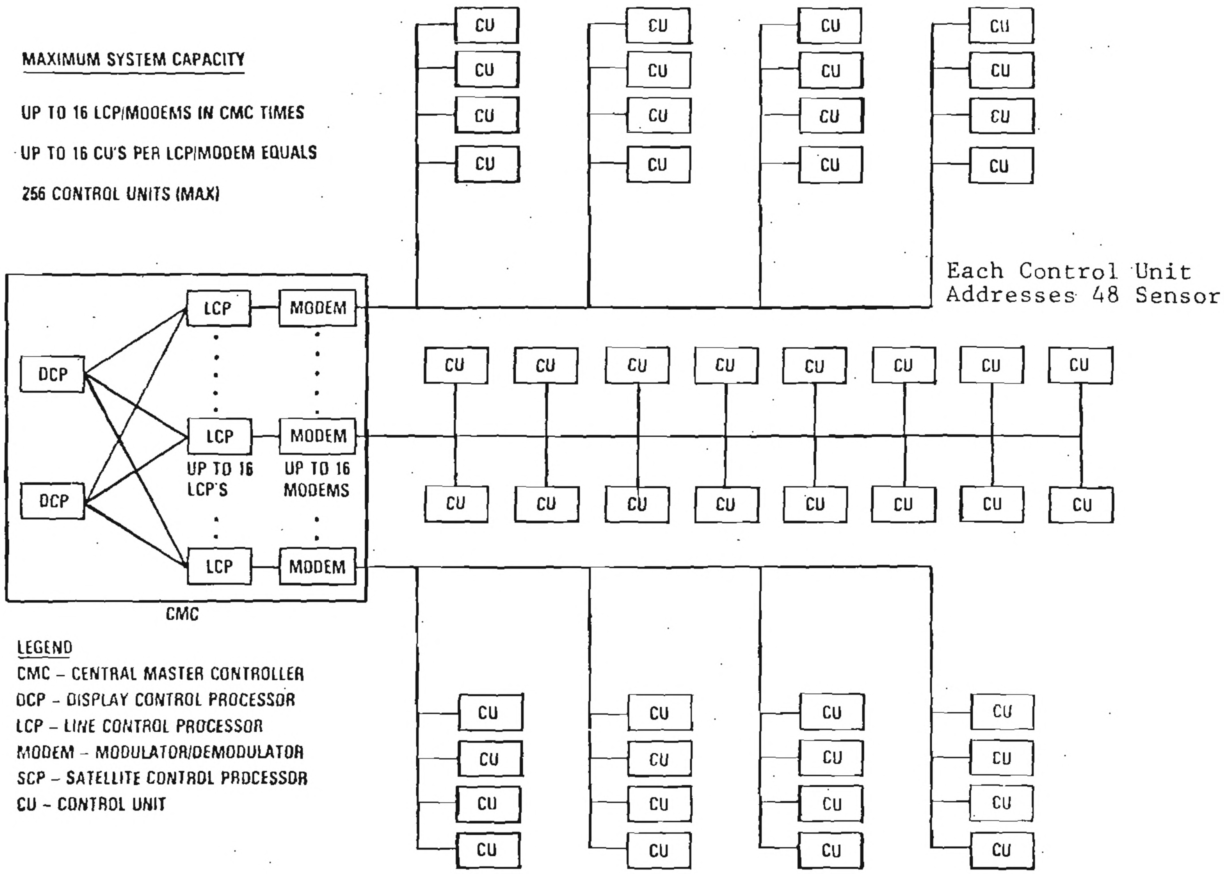


Figure A-11. Sensor architecture of FIDS.

The control unit contains a microprocessor for interfacing with up to 48 individual sensors within a data link distance of 500 feet from the CU. A block diagram of the CU system is given in Figure A-12. Each CU also provides 2 special function channels, 2 deterrent channels (control of lights etc.), a channel for an entry control device (electrically controlled lock etc.), and 10 audio channels for operator monitoring of selected areas.

The FIDS operating philosophy provides a status or operational check on all sensors that is activated by the control equipment. A tamper detection mode is also provided for all of the major system elements (such as the control unit and the CU power supply).

A.4.3 COMMUNICATION FORMAT

This description of the communication format of the FIDS system applies to the interconnection between the line control processors located at the central operator display facility and the control units located at the remote security areas. This multipoint data transmission system (MDTS) enables secure communications between the monitor console and the control units. The data transmission protocol operates in an interrogate-response mode to report alarm and status conditions at control units to the monitor console. The system operates in a half duplex mode over a hard-wire link of up to 10 miles of proprietary No. 22 AWG twisted pair wire having noise characteristics no worse than a 3002 unconditioned channel. The data rate is 1200 bits per second and operation is asynchronous.

The communication system is implemented with a universal asynchronous receiver/transmitter (UART) technique for flexibility and commonality. The word format is an 11-bit word that is defined as follows: 1 start bit, 8 data bits, 1 parity bit (odd), and 1 stop bit.

A method of authenticating the transmitted data is used to provide data security. The communication technique utilizes the capability of the microprocessors in the line control processor and the control unit to perform the processing necessasry for data authentication and implementation of the data transmission protocols.

The hardware provided for data authentication is a single integrated circuit which implements the data standard chosen by the National Bureau of Standards as a federal information processing standard (FIPS46). The integrated circuit is a Western Digital DE2001 which is compatible with the 8085 microprocessor used in FIDS. In addition to the hardware, a software algorithm is implemented along with a protocol to increase the security of the data.

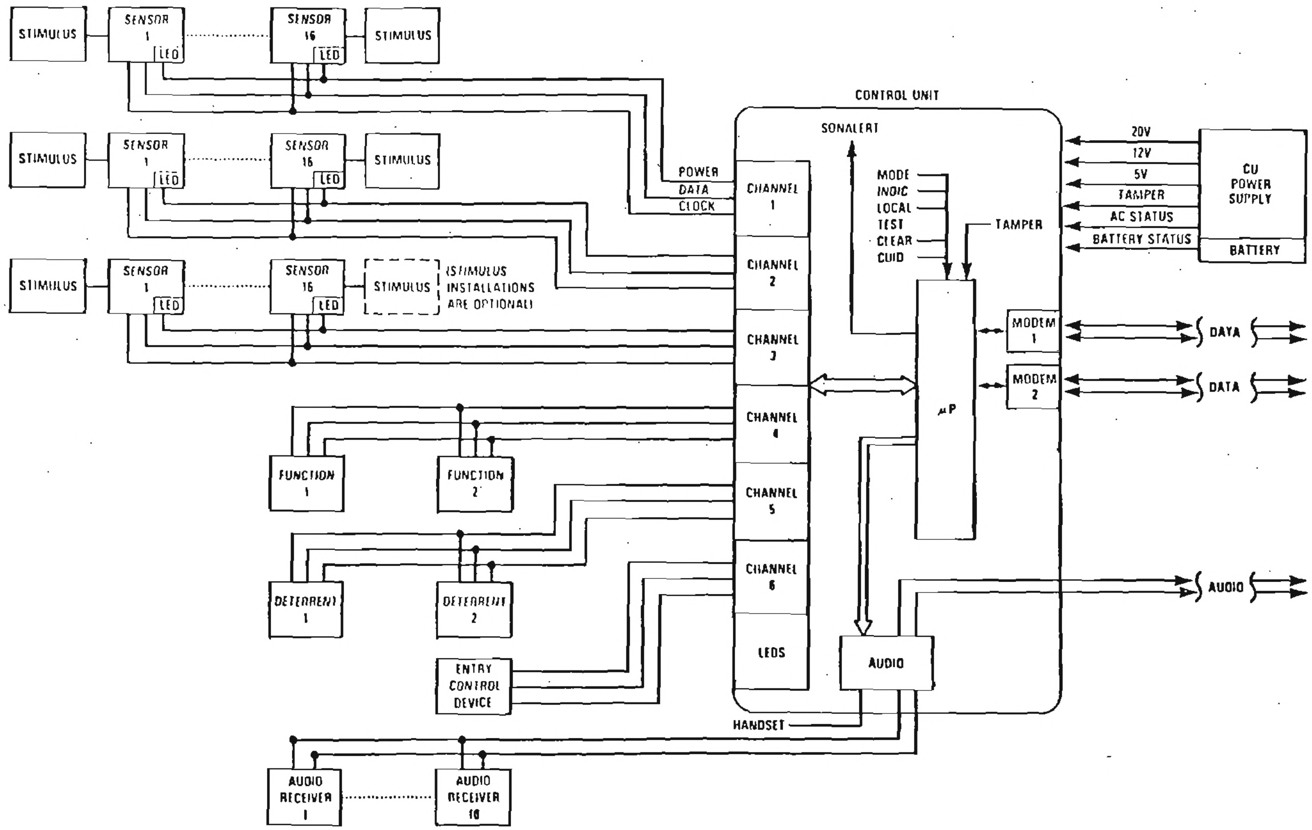


Figure A-12. Block diagram of FIDS Control Unit.

The control unit monitors the output from 48 sensors and acts as the computing mode from these sensors to the central facility. FIDS uses a communication concept to provide comprehensive sensor communictions by providing:

1. Addressability to an individual sensor or remote device.
2. Sufficient generality for use with a variety of sensors, function devices, deterrents, entry control and surveillance devices.
3. Reporting to the control unit sensor configuration information, such as sensor type and presence of a sensor stimulus.
4. Maintenance of line security via an interrogate/response system.
5. Provision for control of sensor stimulus as well as other functions.
6. Provision for reporting of status conditions in addition to internal tamper alarms.

A.4.4 NETTING INTERFACE REQUIREMENTS

The FIDS security system appears to be a well designed concept for the netting of fixed point sensors. The basic communication rate is considered to be too low for use with radar sensors, (even with a high degree of preprocessing. The display is not suitable for displaying the large amounts of data that can be introduced from a netted radar security system. The system does not have spare capacity or expansion capability to accommodate the computing requirements of a netted radar system for the functions of target correlation, track processing, and threat analysis.

The FIDS system does appear to be a good match for combining a netted fixed sensor security system with a netted radar system. The communication format is well engineered and the alarm information can be accessed in the central operator/display facility.

One place to consider accessing the information in the FIDS system is at the line control processor. An interface board could be introduced into the central operator console (16 maximum - one for each LCP) to monitor the normal communications between the FIDS console and the remote area control units. This interface would not alter the operation of the FIDS system, but could provide the overall netted radar-fixed sensor surveillance system with all of the fixed sensor data from FIDS. Correlation of the fixed sensor data with the radar sensor data would be made in the overall netted surveillance system.

A.5 THE BISS SPCDS NETTED SENSOR SECURITY SYSTEM DESCRIPTION

A.5.1 SUMMARY DESCRIPTION

This summary description of a netted fixed sensor security system was prepared for the Georgia Tech concept investigation of netted radar-fixed sensor surveillance systems. This netted fixed sensor system is designed around the BISS Small Permanent Communications and Display Segment (SPCDS) that monitors a number of fixed sensors through nodal interface units. The nodal interface to the sensor array is provided by the Coder-Multiplexer, Sensor, Data (CMSD). This security/surveillance system is designated as the Alarm System, Anti-Intrusion, Restricted Area, AN/GSS-29(V).

The SPCDS is a netted physical security system that connects a number of fixed point sensors to a central operator/display console. The system is connected in a tree configuration through the CMSD interface unit. Intruder detections are indicated on a display with 160 LEDs on a facility map at the operator display.

A block diagram of the system is given in Figure A-13. Each CMSD is capable of monitoring up to 80 sensors of a variety of types. The display system supports up to 4 CMSD units giving the net command of up to 320 sensors units.

The CMSD is a data gathering, storing, processing, and transmitting device for sensor data received from 1 to 80 remote sensor units. It has the facilities for initiating sensor test functions, either on command from remote equipment or automatically at seven hour intervals. The sensor test feature provides an indication of the operational status of the remote sensor units. The CMSD unit is capable of handling up to 80 sensor input signals simultaneously over 3.2 kilometers of AWG No. 19 copper wire, in four groups of 20 inputs per connector.

The CMSD is an impedance sensing device. It recognizes an intrusion alarm signal when the impedance of any of the sensor lines drops belows 400 ohms for a period of 80 milliseconds or longer. A line fault is recognized whenever the impedance of a given sensor line rises above 7.5 kilohms for a period of 200 milliseconds or longer. These conditions are automatically transmitted to the central operator display console.

A.5.2 COMMUNICATION FORMAT

The CMSD unit transmits 5 communication message types to a Local Display Area (LDA) and/or to a Remote Display Area. These message types are

1. Sensor Alarm Messages.
2. Line Fault Messages.

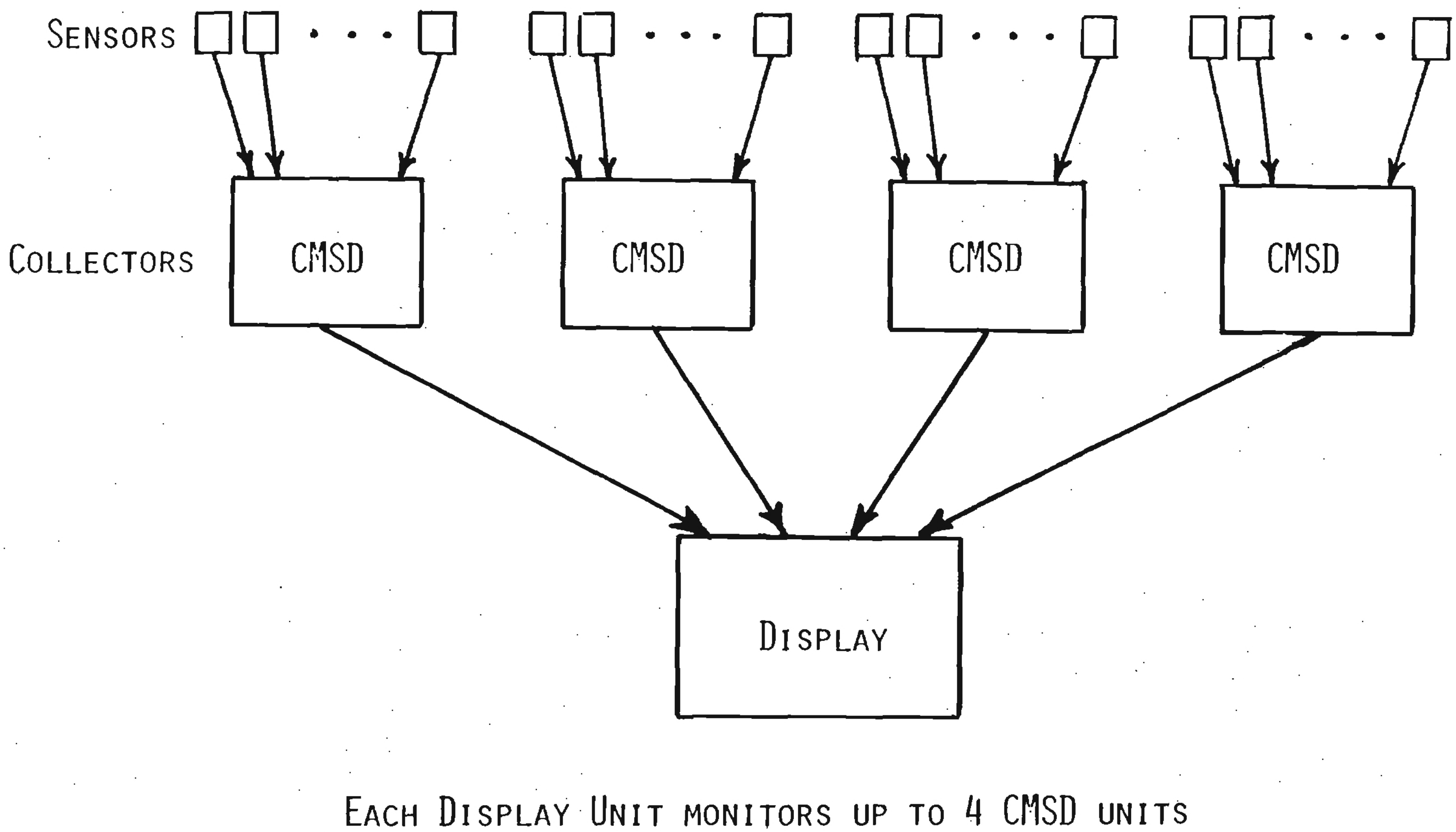


Figure A-13. SPCDS functional block diagram.

3. Failed-Self-Test Messages.
4. Data Link Monitor Messages.
5. Battery Good Link Good Messages.

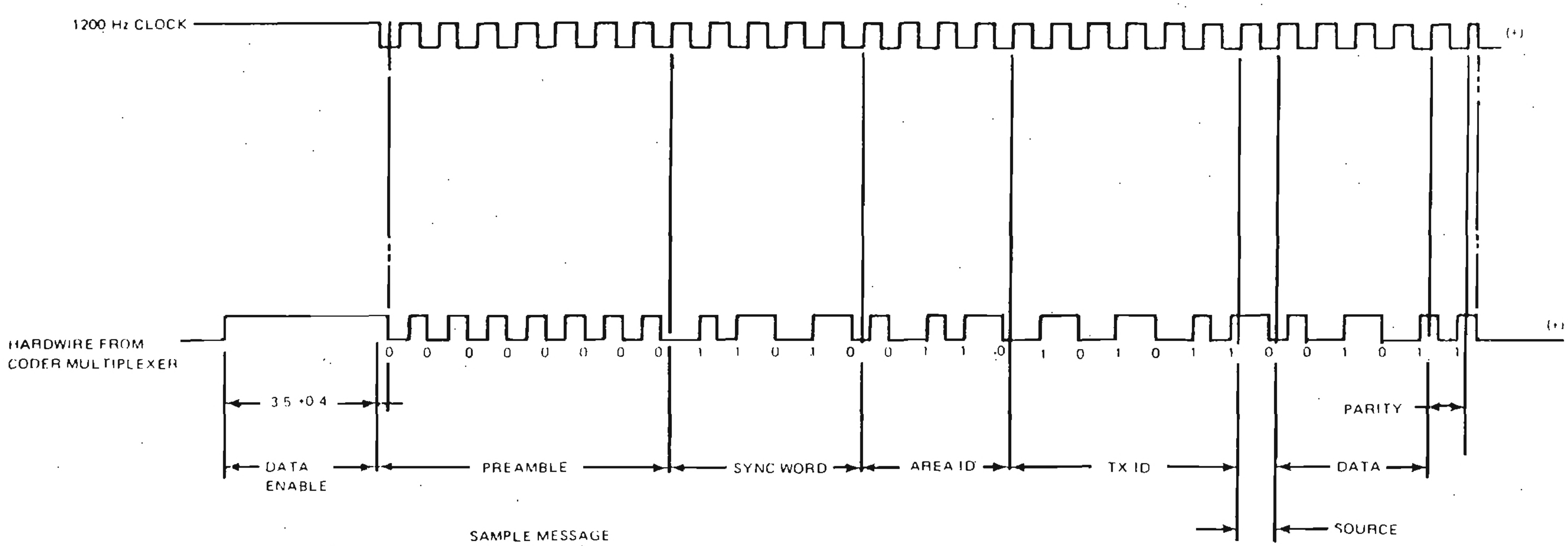
Messages from the CMSD are sent in serial digital format consisting of 29 bits that are clocked out at a 1200 Hertz rate. These bits are assigned as follows:

1. Bits 29 through 22 is a preamble that specifies the formatting of a message.
2. Bits 21 through 17 is the sync word code that allows routing of the message to appropriate remote equipment for further display and processing.
3. Bits 16 through 13 is the area ID that is manually set by switches on the CMSD to represent the assigned area in which the CMSD is placed.
4. Bits 12 through 7 gives the transmitter ID; the first two bit identify the CMSD. The remaining four bits identify the sensor.
5. Bit 6 identifies the source.
6. Bits 5 through 2 contains the data message.
7. Bit 1 is the parity bit for the serial message.

These message formats are shown in more detail in Figure A-14 and in Table A-5.

A.5.3 NETTING INTERFACE REQUIREMENTS

The SPCDS unit does not have the display capability for handling intrusion data from a net of radar sensors. The CMSD unit appears to be a good design for the netted radar-fixed sensor surveillance system being studied. The data rate and formats of the CMSD is adequate for the point sensors, but will <u>not</u> support the higher data rates needed for radar data. This SPCDS concept could be used in the netted radar-point sensor security concept if the output of the CMSD units are interfaced via a suitable interface box. This would allow the sensor information to be accessed without affecting the normal display functions of the SPCDS unit.



SAMPLE MESSAGE

	SYNC WORD					AREA ID				TX ID						SOURCE	DATA				PARITY
BIT	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1
	1	1	0	1	0	0	1	1	0	1	0	1	0	1	1	0	0	1	0	1	1

Figure A-14. SPCDS message format.

TABLE A-5. SPCDS MESSAGE FORMAT.

	PREAMBLE	SYNC WORD	AREA ID	TRANSMITTER ID	SOURCE	DATA	PARITY
BIT	29 28 27 26 25 24 23 22	21 20 19 18 17	16 15 14 13	12 11 10 9 8 7	6	5 4 3 2	1

	SYNC WORD				
BIT	21	20	19	18	17
DATA MESSAGE	1	1	0	1	0

BIT 6	DATA 5 4 3 2	MESSAGE		
0	0 0 0 1	SENSOR	1	ALARM
0	0 0 1 0		2	
0	0 0 1 1		3	
0	0 1 0 0		4	
0	0 1 0 1		5	
1	0 0 0 1	SENSOR	1	FAILED SELF TEST
1	0 0 1 0		2	
1	0 0 1 1		3	
1	0 1 0 0		4	
1	0 1 0 1		5	
1	1 0 0 0	BATTERY GOOD LINK GOOD (ST STARTED)		

ODD PARITY BIT 2–16

	SYNC WORD				
BIT	21	20	19	18	17
LINE SUPERVISION MESSAGE	1	1	1	0	0

BIT 6	5 4 3 2	MESSAGE		
0	0 0 0 1	SENSOR	1	LINE BAD
0	0 0 1 0		2	
0	0 0 1 1		3	
0	0 1 0 0		4	
0	0 1 0 1		5	

APPENDIX B
PROPOSED INTERFACE DESCRIPTIONS FOR SELECTED SENSORS

B.1 NETTED INTERFACE DESCRIPTION FOR SHORT RANGE SECTOR RADARS

B.1.1 INTRODUCTION

This appendix contains the proposed interface requirements for currently available sensors that are to be connected into a netted radar-fixed sensor surveillance system. This requirement description was prepared in support of the Georgia Tech netted radar-fixed sensor concept study and was developed around the netting concepts described in this final technical report.

This section describes the considerations for interfacing short range ground surveillance sector radars into a netted security system with a number of fixed sensors. The background rationale is briefly discussed, and the data format and resolution required for such an interface is presented. When options are possible, the recommended priority for choices is listed. The interface description defined here will accommodate a maximum of eight radars in the net, but will also function well with any number of radars less than the maximum.

B.1.2 BACKGROUND

A netted security system study was performed for the U.S. Air Force Physical Security Systems Directorate (PSSD) by the Georgia Institute of Technology Engineering Experiment Station (GIT/EES) to define concepts for integrating ground surveillance radars into a netted security system along with fixed sensors currently under development such as SPCDS, FIDS, and REMBASS. This study defined the radar unit as a large area sensor system capable of detecting intrusions from a large number of individual resolution cells contained within the radar field of view. Each radar resolution cell can be considered to be equivalent to a fixed sensor unit in terms of a netted system and can best be referenced by its location. Since more than one radar may be used in a surveillance application, provisions must be made for overlapping coverage of given terrain areas. A reference method such as the map grid system is ideal for this target location identification problem.

Automatic detection, tracking, and threat assessment is a major goal of a netted sensor system which involves the integration of radar technology with point sensors. This is necessary to eliminate or supplement the requirement for individual radar operators wherever possible to reduce manpower requirements and increase the effectiveness of the operating security personnel. Personnel and vehicle targets which may be detected by a radar sensor have a wide range of velocities, and the human intruder can rapidly change the velocity and direction of movement. For these reasons, near real time tracking of intruders is a necessity. For real time tracking, the target association and tracking algorithms must be designed to operate primarily on the location and time that a given radar range cell shows the indication of an intrusion. This establishes the requirements for the location and time to be included in a report of a potential target in an occupied resolution cell (ORC).* The resolution requirements for such reports will be developed in the following discussions.

The netted radar-fixed sensor concept is based on automatic association and tracking algorithms for intruders within a defined base area to provide improved rejection of false and nuisance alarms and assist in the interception of potential threats by security forces. Multiple radar coverage of protected areas may be required to maximize the probability of detection and allow for natural overlapping of surveillance zones. This concept requires correlation target data reported from different radars and correlation of data from radars and fixed point sensors. This correlation is accomplished through the use of position location and time-of-occurrence.

Two communication formats must be defined for the radar interface to such a netted system. The first will be concerned with the reporting of data from the radar to the netted sensor system. This message information will be defined as the data word. Secondly, since the radar may have adjustments that can be changed by a local operator, it may be desirable for the netted sensor system operator to also have control access to these adjustments. This communication function will be defined as the command word.

B.1.3 REQUIRED INFORMATION

The position of an occupied resolution cell within a given radar coverage area can be expressed uniquely in Cartesian coordinates such as the UTM map-grid system. While this reference system is in a form that can be easily used in a netting system, it does not represent the form common to most personnel detecting sector radars. The category of

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*Occupied Resolution Cell is defined as a resolution cell within the radar field of view defined by the antenna azimuth beamwidth and the range cell length in which the detected signal has exceeded a threshold indicating the presence of a potential target.

radars discussed here (such as the FOLPEN radar and the Exterior Perimeter Sensor Device (EPSD) a product improvement of the AN/PPS-15(B) are oriented to a detection scenario using a limited number of range rings as shown in Figure B-1. The intrusion report is typically referenced to the range ring location where the intrusion occurred or to the location of the first range ring if they are continuous. The location description of the ORC is fixed with the addition of an azimuth position that is referenced to the radar antenna position.

The definition study of netted radar-fixed sensor security systems has defined association/location algorithms for analyzing the radar ORC reports that are based on the position location and the time of occurrence of the event. This study indicates that the nominal location resolution of the radars available for this function is between 10 and 50 meters. If a worst case design is assumed, a resolution of 10 meters can be selected for an assumed operating area of 10 kilometers radius (the operating area includes all of the netted surveillance area). This would require a maximum resolution of 11 bits binary for both the X and the Y coordinates of the ORC report. In a similar manner, the resolution of the time of occurrence of the report can be defined to be a one second resolution over a 24 hour period (17 bits). This defines basic location and time resolution needed in a netting central processor to correlate ORC data from radars with overlapping coverage and from radars and fixed sensors.

B.1.4 DESIRED INFORMATION

B.1.4.1 Data Word

There are several types of information in the data word and in the command word that are desirable from the netted radar-fixed sensor standpoint. The ORC position may be uniquely referenced by X-Y grid coordinates in the UTM map system as discussed above or by a range and azimuth reading relative to the location of the radar. If the ORC locations are described in polar coordinates, then the location and pointing direction of the radar must be known at the central netting processor with a resolution nominally equivalent to 10 meters. Azimuth reference for the radar pointing direction or for the ORC report should be referenced to grid-north of the map system.

The resolution requirements for the position and time of an ORC report given above are the maximum values defined for a netted surveillance system containing a large number of fixed sensors and a number of radars. This is the resolution required within the netting computer. The minimum resolution for the ORC reports can be examined by considering the capabilities of the specific radar units. The basic location reporting scenarios are illustrated in Figure B-2.

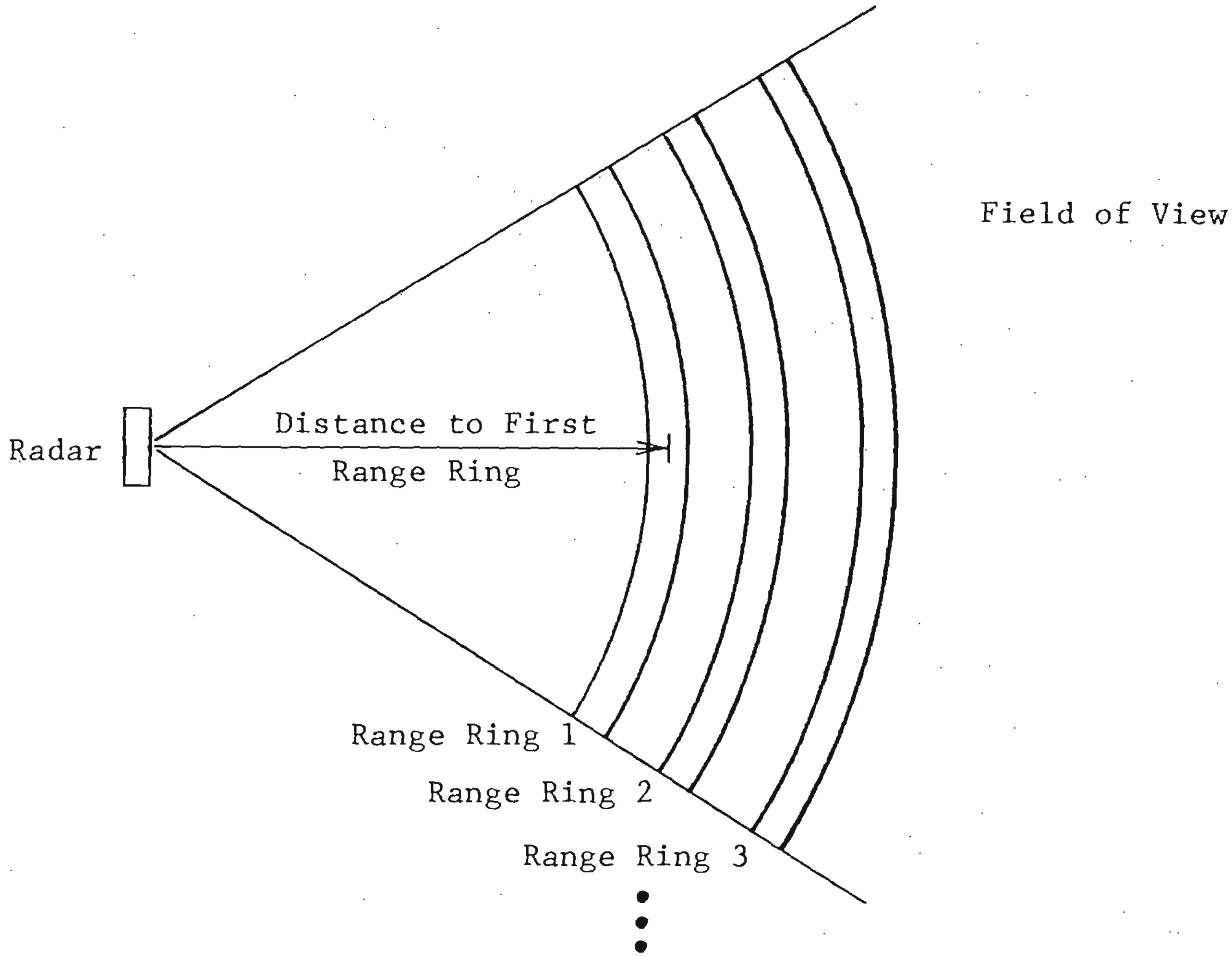


Figure B-1. Typical range ring detection zones.

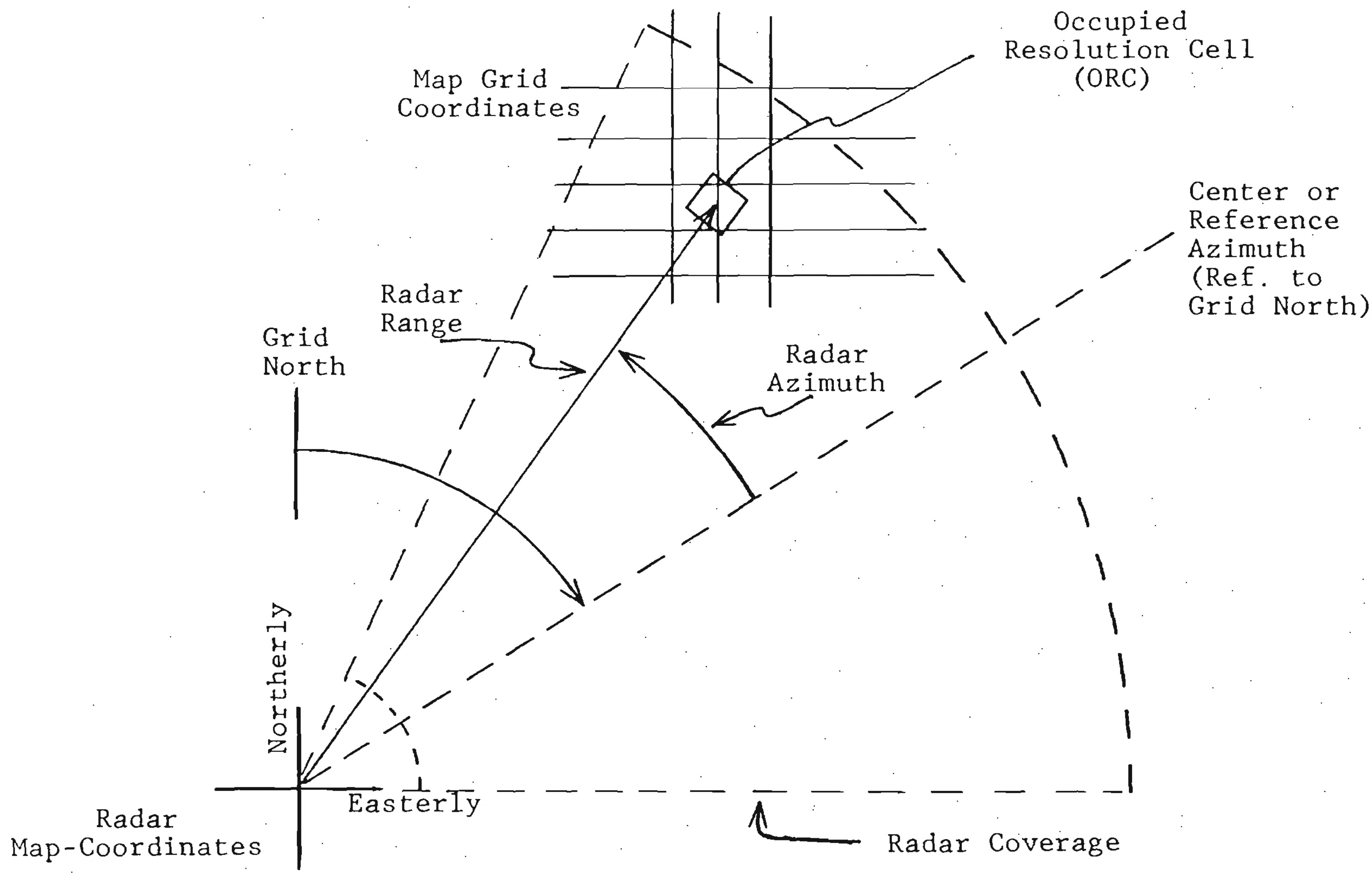


Figure B-2. Two basic ORC location reporting scenarios.

The minimum resolution requirements for a short range sector scanning radar can be defined in terms of its maximum detection range. If a range resolution of 30 meters is assumed for a 4 kilometer maximum detection range (typical for the EPSD version of the AN/PPS-15(B), a binary resolution of 8 bits is required. A nominal azimuth resolution of 6 degrees over a sector coverage of 180 degrees would require a binary resolution of 5 bits. This minimum value of location word resolution would require 13 bits total and would require that the position and pointing direction of each radar be known accurately at the netting computer. This value is coarser than the 10 meter maximum location resolution reporting capability defined for the automatic associating/tracking algorithms used in the netted radar-fixed sensor system study and, thus, would not use the least significant bits in reporting.

Two ORC reporting methods may thus be defined for describing the position in an ORC location report. A position report using the UTM map coordinates is preferred, but this requires that the conversion from polar coordinates to Cartesian coordinates be made at the radar. The information required in the data word is defined in Table B-1 for both position descriptions presented above. The radar units are to be capable of operation via remote RF data transmission links to facilitate fast set-up for the security system. For this reason, the radar interface will follow the Physical Security Systems Directorate Specification Number SEIWIG-005 on "Interface Specification RF Data Transmission Interfaces For DOD Physical Security Systems." This document defines the data message inputted to the RF transmitter as a binary signal coded at an information bit rate of 1200 + or - 36 bits per second. Each transmitted message will have a common preamble (message bits 1 - 9) consisting of a sequence of eight "zeros" followed by a "one." The preamble is followed by a message code field (bits 10 - 13) containing a preassigned code. The message data field starts with bit 14. The BISS and the REMBASS systems have traditionally used a 29 bit digital message which is too small to accommodate the data defined in Table B-1. The FIDS message is made up of varying numbers of 11 bit bytes following eight or more zeros. The first byte of a FIDS message incorporates the start bit (bit 9) and the message code field (bits 10 - 13). The referenced specification does not limit the message length, but it is desirable for the radar interface description to follow a defined format if a suitable one exists. The FIDS format varies from three bytes to nine bytes, corresponding to a range of 41 bits to 107 bits per message. This FIDS format is sufficient to accommodate either of the data requirements listed in Table B-1.

TABLE B-1. DATA WORD INFORMATION

Item	Desired Resolution	Minimum Requirements
Preamble	9 bits	9 bits
Message Code	4 bits	4 bits
Sensor Type	2 bits	2 bits
Radar ID	3 bits	3 bits
Report Type	2 bits	2 bits
Report Subclass	5 bits	5 bits
Time	17 bits	17 bits
ORC Location	22 bits	13 bits
Parity	1 bit	1 bit
Total Bit Requirements	65 bits	56 bits

The message data field of the ORC report contains a number of data items relating the radar system and the location of the occupied resolution cell. The definition of these items are given in Table B-2.

B.1.4.2 Command Word

The command word controls the position of the radar and the signal processor located with the radar set. The command word serves two basic functions and has been divided into an initialization format and an operational format. The initialization format of the command word is used to define (or redefine - in the case of fast-set up security systems) the initial conditions of location coordinates, time, and operating mode of the radar and signal processor. The operational format of the command word is used as the routine communication form with the remote radar/signal processor systems. This command word is used to: (1) change the direction of the sector scan center, (2) control the width of the sector scan, (3) change the position of the range bins, (4) control the distance between adjacent range bins, (5) provide a routine synchronization of the reference clock contained in the radar signal processor, (6) define the operating mode of the radar system, (7) initiate self test algorithms within the radar and signal processor, and (8) adjust the clutter filter cutoff frequency of the signal processor.

The command word is defined for remote RF operation in a manner similar to that selected for the data transmission links. The command word will follow the referenced SEIWG-005 specification described above. The message contents and bit requirements of the two formats of the command word are listed in Table B-3 and Table B-4. The definitions of the various message items are given in Table B-5.

B.1.5 RECOMMENDED COMMUNICATION WORD FORMATS

The communication requirements defined for the data words and the command words are intended to accommodate several generic types of short-range radar sets. The definitions of the message items recognize that the actual capabilities of a given radar design will differ from the desired capabilities allowed for in the communication interface definition. In this sense, the definitions made in this specification are intended to be universal enough to accommodate future security system requirements and available equipment designs.

The recommended communication word formats follow the FIDS format using groups of 11-bit bytes. The data word has been defined with a requirements of at least 65 bits. Two formats of the command word have been defined with requirements of at

TABLE B-2. DEFINITION OF DATA WORD

1. Sensor Type - 2 bits -- defines 4 possible sensor types
    a. Radar
    b. SPCDS
    c. FIDS
    d. REMBASS
2. Radar ID - 3 bits -- identifies one of 8 possible radars in net
3. Report Category - 2 bits -- defines 4 radar report categories
    a. Occupied Resolution Cell (ORC) Report
    b. Built In Test (BIT) Failure Report
    c. Tamper Report
    d. Self Test Report
4. Report Subclass - 5 bits -- identifies report type under above categories or velocity information for ORC Report
    a. ORC Report
        (1) Speed - 4 bits defines ORC velocity category or velocity bin number
        (2) ORC Direction - 1 bit - defines in/out direction of ORC modem
    b. BIT Report
        (1) Equipment Failure
        (2) Degraded Performance
    c. Tamper Report
        (1) Physical Tampering/Equipment Entry
        (2) Electromagnetic Countermeasures (Jamming)
        (3) Proximity Detectors (Personnel nearby)
        (4) Sensor Moved (detects possible change in pointing direction)
    d. Self Test
        (1) Acknowledge Self Test Request
        (2) Self Test Completed - System OK
        (3) Equipment Failure
        (4) Degraded Performance

TABLE B-2. DEFINITION OF DATA WORD (Continued)

e. Communication

(1) Link Check

5. Time - 17 bits -- time of occurrence of report (one second resolution in 24 hour day)

6. ORC Location

a. First Priority: Cartesian Coordinates - 22 bits

b. Second Priority: Polar Coordinates - 13 bits

7. Parity - 1 bit -- An even or odd parity check on data word

TABLE B-3. COMMAND WORD INFORMATION
(Initialization Format)

Item	Resolution Desired
Preamble	9 bits
Message Code	4 bits
Radar ID	3 bits
Command Subclass	2 bits
Radar Location (X - position -- 11 bits) (Y - position -- 11 bits)	22 bits
Time	17 bits
Operating Mode	4 bits
Self Test Initiate	2 bits
Parity Check	1 bit
Total Bit Requirements	64 bits

TABLE B-4. COMMAND WORD INFORMATION
(Operational Format)

Item	Resolution Desired
Preamble	9 bits
Message Code	4 bits
Radar ID	3 bits
Command Subclass	2 bits
Direction of Scan Center	11 bits
Width of Scan Sector	6 bits
Range Bin Position	10 bits
Distance Between Range Bins	3 bits
Time	17 bits
Operating Mode	4 bits
Self Test Initiate	2 bits
Clutter Filter Cutoff Frequency	3 bits
Parity Check	1 bit
Total Bit Requirements	75 bits

TABLE B-5. DEFINITION OF COMMAND WORD

1. Radar ID - 3 bits -- Identifies one of 8 possible radars in net.

2. Command Subclass - 2 bits -- Defines type of Command Message.

3. Direction of Scan Center - 11 bits -- Defines pointing direction of sector center with a resolution of 0.2 degrees over a range of 360 degrees.

4. Width of Scan Sector - 6 bits -- Defines sector width with a resolution of 5 degrees over a maximum sector width of 180 degrees.

5. Range Bin Position - 10 bits -- Defines position of reference bin (for example: inner range bin) from radar with a resolution of 5 meters over a maximum range of 4 kilometers.

6. Distance Between Range Bins - 3 bits -- Defines separation of adjacent range bins (For example: the EPSD has two range bin separation distances - 50 meters and 500 meters).

7. Time - 17 bits -- Time synchronization for reference clock in radar.

8. Operating Mode - 4 bits -- Defines the operating mode of the radar. This quantity is specific to each radar system design (For example: the EPSD may operate in the Search or Track Mode). First Mode Bit defines Manual/Computer Control of radar.

9. Radar Location - 22 bits -- Initializes the radar signal processor with the coordinates of the radar set.

10. Self Test Initiate - 2 bits -- Initiates Self Test routines designed into the surveillance radars. (Includes a Communication/Data Link Test.)

11. Clutter Filter Cutoff Frequency - 3 bits -- Controls possible settings of the clutter rejection filter.

12. Parity Check - 1 bit -- An even or odd parity check on the data word.

least 64 and 75 bits. A grouping of seven 11-bit bytes will accommodate all three word formats and is the recommended word format for the netted radar interface. The suggested bit assignments for the three 7-byte words are given in Figures B-3, B-4, and B-5. The definitions of the message items used in these figures are given in the data word definitions (Table B-2) and the command word definitions (Table B-5).

B.1.6 COMMUNICATION RATES

The maximum bit rates are defined by the referenced SEIWIG-005 specification at 1200 baud. The 7-byte (11 bits per byte) word format limits the communication rate for both the data words and the command words to a maximum of 15.6 words per second at each radar interface. While this is more than adequate for the limited number of command words expected, it will pose a limitation on the maximum number of ORC reports that can be accommodated from a given radar set. This reporting rate will handle two reports per range bin for an 8-range bin signal processor which accommodates the EPSD and the current capabilities of the FOLPEN radar systems.

The proposed communication word formats will accommodate the netting of up to eight short range sector scan personnel detecting radars with a security system using fixed sensors. The interface definition will allow a bidirectional RF communication/data link to be used for fast set-up situations and will also function over other communication mediums such as hard wires. The word formats are similar to the formats used in the FIDS sensor netting system and contain some unassigned bits to allow for future expansion.

B.2 RADAR SENSOR INTERFACE DESCRIPTION FOR WIDE AREA SURVEILLANCE RADARS

This section discusses requirements for the data and command links for a wide area surveillance radar operating within a netted radar-fixed sensor surveillance system. While this interface description parallels the proposed interface requirements for the short range sector scan radars, it has not been developed as a stand-alone document since no specific production radar has currently been identified with this application. The modified AN/PPS-5 radar used in the LARIAT feasibility demonstration has been used in this report as a benchmark system since it meets many of the operating parameters desired in an area surveillance radar for a netted surveillance applications.

The netting requirements for an area surveillance radar differ from the short range sector radar scan system by a significant increase in the number of resolution cells

BYTE NUMBER	BIT NUMBER 1	2	3	4	5	6	7	8	9	10	11
1	PREAMBLE									MESSAGE	
2	CODE		SENSOR TYPE		RADAR I.D.			REPORT TYPE		REPORT	
3	SUBCLASS		TIME								
4	TIME (continued)										
5	X-position										
6	Y-position									PARITY BIT	
7											

Figure B-3. Suggested data word format.

BYTE NUMBER	BIT NUMBER 1	2	3	4	5	6	7	8	9	10	11
1	PREAMBLE									MESSAGE	
2	CODE		RADAR I. D.			COMMAND SUBCLASS		RADAR LOCATION:			
3	X-position							RADAR LOCATION:			
4	Y-position							TIME			
5	TIME (continued)										
6	TIME (cont.)		OPERATING MODE				SELF TEST INITIATE		PARITY BIT		
7											

Figure B-4. Suggested command word format. (Initialization Format)

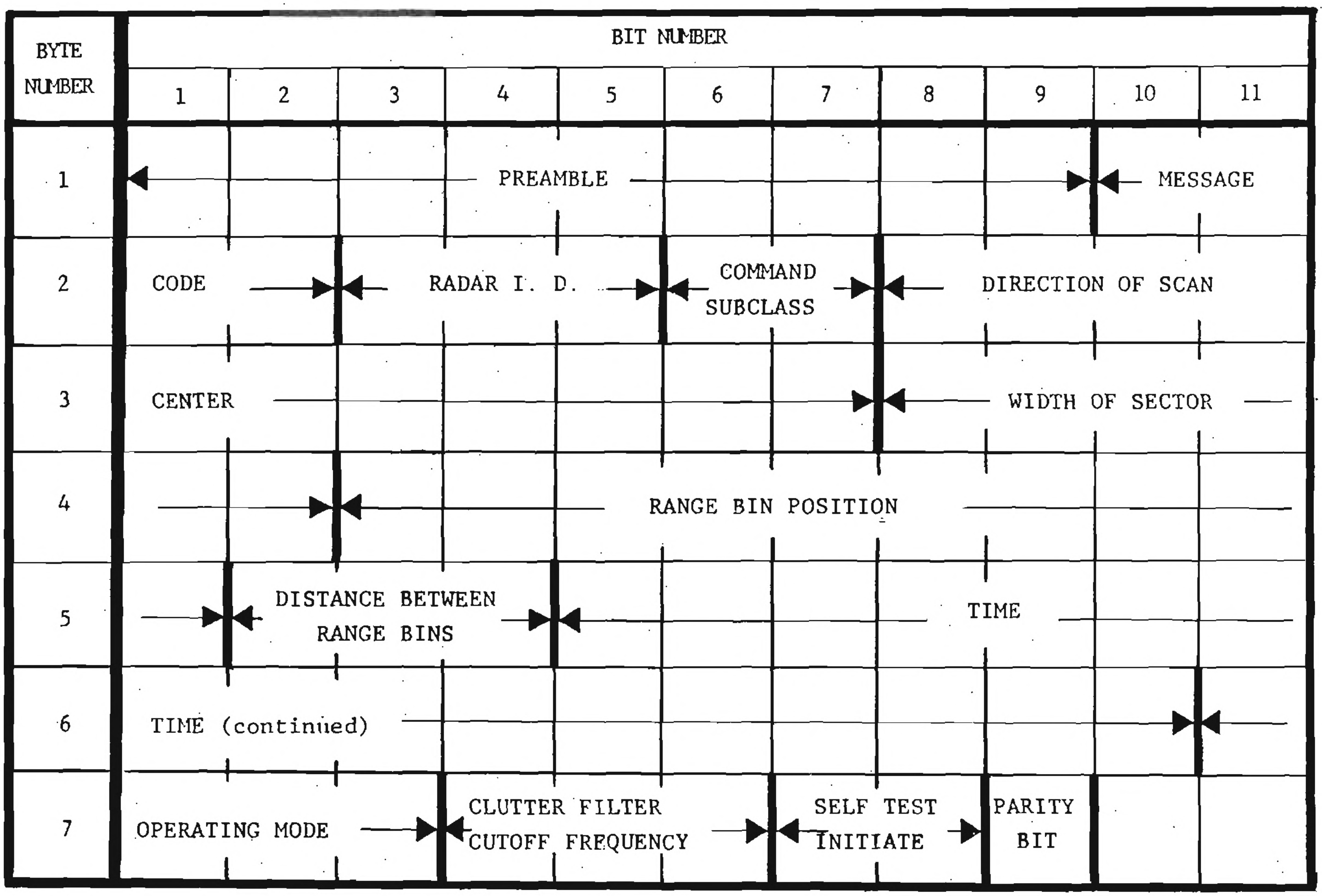


Figure B-5. Suggested command word format. (Operational Format) possible for the area surveillance case. The interface description for the area radar will follow the Physical Security Systems Directorate Specification Number SEIWIG-005 on "Interface Specification RF Data Transmission Interfaces For DOD Physical Security Systems" using a format similar to that specified for the sector coverage radar.

The display return from isolated radar targets is useful in identifying the class or type of target. While this information can be very useful to the radar operator or to the netted surveillance surveillance system, it carries some additional bandwidth requirements over that accommodated within the interface to the short range sector scan radar systems. The data link to this radar will be used for the ORC reports to the netting computer and for any position reports from the optional IFF system described in this report. An additional option for monitoring the radar target Doppler from the area surveillance radar will be handled as a parallel interface.

The bandwidth requirements of the Doppler signal is controlled by the Nyquist sampling rate. In a pulse Doppler system, this will be approximately one-half of the pulse repetition frequency (PRF). The benchmark AN/PPS-5 radar had a PRF of 2 kilohertz, giving a bandwidth of the Doppler audio channel in excess of 2 kilohertz. The serial digital channel specified in the SEIWIG-005 requires that the Doppler signal be digitized before encoding on the data link. If a 9-bit resolution is assumed (8 bits plus sign bit) to give a 40 dB peak dynamic range, then a minimum bit rate requirement of 9000 bits per second would be needed for the above example. This clearly illustrates that the use of the remote Doppler monitoring option must be supported by a wide-band data link. Since this option may not be used for all applications of the area surveillance radar, the ORC reporting data link will be specified as the primary interface to the netting computer, and the Doppler return channel will be specified as an optional auxiliary communication channel.

The ORC reporting data link to the area radar is proposed to contain one additional ORC position report per data word over that used in the sector scan radar interface format. This will expand the basic 7 byte word of the short range sector scan radar interface to a total of 9 bytes (11 bits per byte). The data word bit requirements are given in Table B-6. The definition of the items used in the data word are found in Table B-7. This increased bit count of 9 bytes per words will reduce the data word rate to 12.1 words per second at each area radar interface, but it will increase the ORC reporting rate to an average of 24.2 reports per second per radar. The proposed data word communication format is illustrated in Figure B-6; in this figure, 5 bits are provided for each ORC report for an RCS estimate as a future expansion to the netted system

TABLE B-6. DATA WORD INFORMATION FOR AREA SURVEILLANCE RADAR

Item	Resolution Desired
Preamble	9 bits
Message Code	4 bits
Sensor Type	2 bits
Radar ID	3 bits
Report Type	2 bits
Report Subclass	5 bits
Time	17 bits
ORC Location	
Number 1	22 bits
Number 2	22 bits
RCS Estimate	
ORC 1	5 bits
ORC 2	5 bits
Parity	1 bit
Total Bit Requirements	97 bits

TABLE B-7. DEFINITION OF DATA WORD FOR AREA SURVEILLANCE RADAR

1. Sensor Type - 2 bits -- defines 4 possible sensor types
   a. Radar
   b. SPCDS
   c. FIDS
   d. REMBASS

2. Radar ID - 3 bits -- identifies one of 8 possible radars in net

3. Report Category - 2 bits -- defines 4 radar report categories
   a. Occupied Resolution Cell (ORC) Report
   b. Built In Test (BIT) Failure Report
   c. Tamper Report
   d. Self Test Report

4. Report Subclass - 5 bits -- identifies report type under above categories or velocity information for ORC Report
   a. ORC Report
      (1) Speed - 4 bits defines ORC velocity category or velocity bin number
      (2) ORC Direction - 1 bit - defines in/out direction of ORC modem
   b. BIT Report
      (1) Equipment Failure
      (2) Degraded Performance
   c. Tamper Report
      (1) Physical Tampering/Equipment Entry
      (2) Electromagnetic Countermeasures (Jamming)
      (3) Proximity Detectors (Personnel nearby)
      (4) Sensor Moved (detects possible change in pointing direction)
   d. Self Test
      (1) Acknowledge Self Test Request
      (2) Self Test Completed - System OK
      (3) Equipment Failure
      (4) Degraded Performance
   e. Communication
      (1) Link Check

5. Time - 17 bits -- time of occurrence of report (one second resolution in 24 hour day)

6. ORC Location - 44 bits -- defines the X-Y position of two ORC'S with a resolution of 11 bits per coordinate

7. ORC RCS Estimate - 10 bits -- a reporting capability for RCS estimate of two ORC targets with a resolution of 5 bits per report.

8. Parity - 1 bit -- an error or odd parity check on data word

BYTE NUMBER	BIT NUMBER 1	2	3	4	5	6	7	8	9	10	11
1	PREAMBLE									MESSAGE	
2	CODE		SENSOR TYPE		RADAR I.D.			REPORT TYPE		REPORT	
3	SUBCLASS			TIME							
4	TIME (continued)										
5	ORC 1 X-position										
6	ORC 1 Y-position										
7	ORC 2 X-position										
8	ORC 2 Y-position										
9	ORC 1 RCS Estimate			ORC 2 RCS Estimate					PARITY BIT		

Figure B-6. Data word format for area surveillance radar.

capability. This format parallels that used for the FIDS message and the general format selected for the proposed short range radar sector scan radar interface requirements. This information would be used for adjusting the search area in the ORC association algorithms.

The command link to the area surveillance radars will be similar to that used in the sector radar interface (described in Section B.1). The command link will use separate word formats for the initialization mode and operational mode. The bit requirements for these two command word formats are given in Tables B-8 and B-9. The definitions of the terms used in the command words are given in Table B-10. The proposed word formats for these two functions are illustrated in Figures B-7 and B-8.

The maximum bit rates for the ORC reporting channel and the command link channel are defined by the referenced SEIWIG-005 specification at 1200 baud. The proposed communication word formats will accommodate the netting of two or more area surveillance radars into a netting computer as defined in the study scenario. These interface definitions will allow a bidirectional RF communication/data link to be used for fast set-up requirements and will also function over other communication mediums such as hard wires. The separate communication channel for the Doppler target return can also be handled over a dedicated wideband RF link or over a quality hardwire system. These proposed word formats are similar to the formats used in the FIDS sensor netting system and are considered general enough to allow the use of different area surveillance radars. This proposed command/data link format will accommodate several area radars into the netting computer if required.

B.3 NETTED INTERFACE FOR BISS SPCDS SYSTEM

This section describes an interface concept which will allow connection of the BISS SPCDS system to the proposed netted system. The interface for the SPCDS should be similar in format to those proposed for the sector scan and area radars in order to simplify the communications problem. However, since the radar interface is much more complex than the SPCDS interface the interface, format will be much simpler for the case of the SPCDS system.

One of the goals of the netted system concept is to provide for netting of various sensor systems without interfering with the stand alone capabilities of the system. Ideally, the interface to the SPCDS system should not involve major modifications to the system and must not prevent the system being used in its normal operational mode. Fortunately, this is achievable for the SPCDS system if the interface to the net is made

TABLE B-8. COMMAND WORD INFORMATION
(Initialization Format)

Item	Resolution Desired
Preamble	9 bits
Message Code	4 bits
Radar ID	3 bits
Command Subclass	2 bits
Radar Location (X - position -- 11 bits) (Y - position -- 11 bits)	22 bits
Time	17 bits
Operating Mode	4 bits
Self Test Initiate	2 bits
Parity Check	1 bit
Total Bit Requirements	64 bits

TABLE B-9. COMMAND WORD INFORMATION
(Operational Format)

Item	Resolution Desired
Preamble	9 bits
Message Code	4 bits
Radar ID	3 bits
Command Subclass	2 bits
Scan Mode	1 bit
Scan Diretion	1 bit
Scan Speed	2 bits
Sector Scan Center Azimuth	11 bits
Width of Scan Sector	6 bits
Range Bin Position	10 bits
Time	17 bits
Operating Mode	4 bits
Self Test Initiate	2 bits
Clutter Filter Cutoff Frequency	3 bits
Parity Chck	1 bit
Total Bit Requirements	76 bits

TABLE B-10. DEFINITION OF COMMAND WORD FOR AREA SURVEILLANCE RADAR

1. Radar ID - 3 bits -- Identifies one of 8 possible radars in net.

2. Command Subclass - 2 bits -- Defines type of Command Message.

3. Scan Mode - 1 bit -- Defines Continuous or Sector Scan Mode.

4. Scan Direction - 1 bit -- Defines direction of Continuous Scan Mode.

5. Scan Speed - 2 bits -- Defines scan speed (4 possible).

6. Sector Scan Center Azimuth - 11 bits -- Defines pointing direction of sector center with a resolution of 0.2 degrees over a range of 360 degrees.

7. Width of Scan Sector - 6 bits -- Defines sector width with a resolution of 5 degrees over a maximum sector width of 180 degrees.

8. Range Bin Position - 10 bits -- Defines position of reference bin (for example, inner range bin) from radar with a resolution of 5 meters over a maximum range of 4 kilometers.

9. Time - 17 bits -- Time synchronization for reference clock in radar.

10. Operating Mode - 4 bits -- Defines the operating mode of the radar. This quantity is specific to each radar system design. First Mode Bit defines Manual/Computer Control of radar.

11. Radar Location - 22 bits -- Initializes the radar signal processor with the coordinates of the radar set.

12. Self Test Initiate - 2 bits -- Initiates Self Test routines designed into the surveillance radars. (Includes a Communication/Data Link Test).

13. Clutter Filter Cutoff Frequency - 3 bits -- Controls possible settings of the clutter rejection filter.

14. Parity Check - 1 bit -- An even or odd parity check on the data word.

<table>
<tr><th rowspan="2">BYTE NUMBER</th><th colspan="11">BIT NUMBER</th></tr>
<tr><th>1</th><th>2</th><th>3</th><th>4</th><th>5</th><th>6</th><th>7</th><th>8</th><th>9</th><th>10</th><th>11</th></tr>
<tr><td>1</td><td colspan="9">PREAMBLE</td><td colspan="2">MESSAGE</td></tr>
<tr><td>2</td><td colspan="2">CODE</td><td colspan="3">RADAR I. D.</td><td colspan="2">COMMAND SUBCLASS</td><td colspan="4">RADAR LOCATION:</td></tr>
<tr><td>3</td><td colspan="7">X-position</td><td colspan="4">RADAR LOCATION:</td></tr>
<tr><td>4</td><td colspan="7">Y-position</td><td colspan="4">TIME</td></tr>
<tr><td>5</td><td colspan="11">TIME (continued)</td></tr>
<tr><td>6</td><td colspan="2">TIME (cont.)</td><td colspan="4">OPERATING MODE</td><td colspan="2">SELF TEST INITIATE</td><td>PARITY BIT</td><td></td><td></td></tr>
<tr><td>7</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

Figure B-7. Command word format for area surveillance radar. (Initialization Mode)

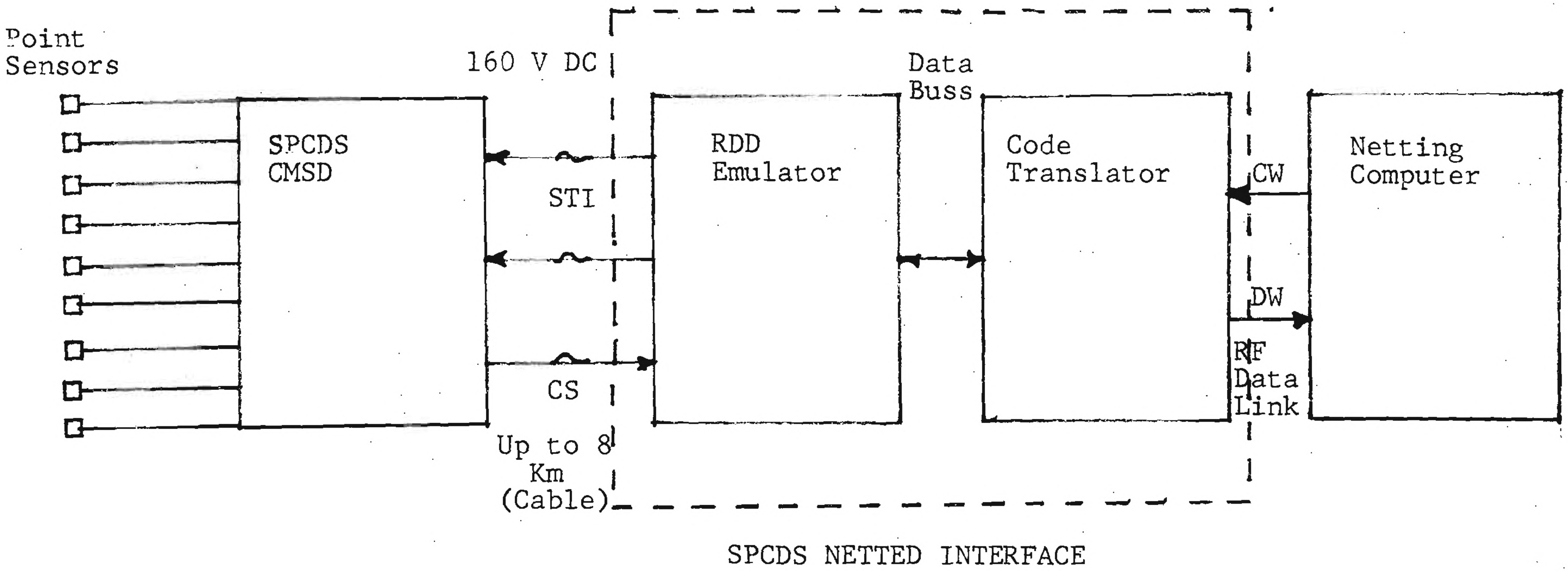
<table>
<tr><th rowspan="2">BYTE NUMBER</th><th colspan="11">BIT NUMBER</th></tr>
<tr><th>1</th><th>2</th><th>3</th><th>4</th><th>5</th><th>6</th><th>7</th><th>8</th><th>9</th><th>10</th><th>11</th></tr>
<tr><td>1</td><td colspan="9">PREAMBLE</td><td colspan="2">MESSAGE</td></tr>
<tr><td>2</td><td colspan="2">CODE</td><td colspan="3">RADAR I. D.</td><td colspan="2">COMMAND SUBCLASS</td><td>SCAN MODE</td><td>SCAN DIREC-TION</td><td colspan="2">SCAN SPEED</td></tr>
<tr><td>3</td><td colspan="11">SECTOR SCAN CENTER AZIMUTH</td></tr>
<tr><td>4</td><td colspan="6">SECTOR SCAN WIDTH</td><td colspan="5">RANGE BIN</td></tr>
<tr><td>5</td><td colspan="5">POSITION</td><td colspan="6">TIME</td></tr>
<tr><td>6</td><td colspan="11">TIME (continued)</td></tr>
<tr><td>7</td><td colspan="4">OPERATING MODE</td><td colspan="3">CLUTTER FILTER CUTOFF FREQUENCY</td><td colspan="2">SELF TEST INITIATE</td><td>PARITY BIT</td><td></td></tr>
</table>

Figure B-8. Command word format for area surveillance radar. (Operational Mode) at the so-called "Coder, Multiplexer, Sensor, Data" (CMSD) unit as is shown in Figure B-9. The CMSD scans up to 79 remote point sensors in a periodic manner and generates a serial digital message which reports the status of the sensors (see Appendix A). Normally, this serial message is sent over a distance of up to 8 km to the so-called "Receiver, Digital Data" (RDD) which processes the data for display. Fortunately, the CMSD is designed to drive up to two RDD units, although the normal mode involves only one. Thus, the extra RDD output is available to interface to the netted system as shown in Figure B-9. The interface circuitry consists of an RDD emulator, a code translator, and an RF link driver. As far as the CMSD is concerned, the interface looks like a second RDD, and the interface unit can be located up to 8 km away from the CMSD. Since the data format is already a serial digital word, all the code translator has to do is to transform the code format to that appropriate for the RF data link.

As in the case of the radar interfaces, both a data word and a command word are needed for communication (two way communication). Table B-11 defines the desired data word for the SPCDS interface. The format follows as closely as possible the format used for the radar interfaces and includes all of the information available from the CMSD unit. The data word includes sensor type (SPCDS), area ID (one of four possible CMSD units), report category (alarm, self test, tamper, or line fault), report subclass (two speed catagories, failed self test, tamper report, or line fault), time (one second per day resolution), location of sensor, and parity check. Figure B-10 gives the data word format and indicates the various message reports. The SPCDS system has a two way communication capability. Thus, a command word from the netted system to the the CMSD is needed. Table B-12 gives the message definition for the command word. The format for the command word includes sensor type, sensor ID, command subclass (either initiate self test or set time), time reference, and parity check. Thus, the CMSD sees the two way interface that it expects and the RF link sees the format it expects. The specific format for the command word is given in Figure B-11.

B.4 NETTED INTERFACE FOR FIDS SYSTEM

The desired goals for the FIDS system interface are similar to those for the SPCDS system. That is the FIDS system should operate in the stand-alone mode without interference from the netted interface, and all of the data available from the system should be transmitted to the netted system. This can be accomplished for the FIDS in a manner similar to that used for the SPCDS system. Figure B-12 gives a block diagram of the netted interface of the FIDS system. For this case, one of the 16 possible line



- o INTERFACE EMULATES RDD FOR SPCDS
- o GENERATE NETTED SYSTEM COMPATIBLE CODE FOR INTERFACE TO RF LINK

Figure B-9. Block diagram of SPCDS to netted system interface.

TABLE B-11. DEFINITION OF DATA WORD FOR SPCDS

1. Sensor Type - 2 Bits
   a. Radar
   b. SPCDS
   c. FIDS
   d. REMBASS

2. Area ID - 2 Bits - Identifies One of Four CMSD Units

3. Report Catagory - 2 bits - Defines Four Report Catagories
   a. Sensor Alarm
   b. Failed Self Test
   c. Tamper Report
   d. Line Fault

4. Report Subclass - 7 Bits
   a. Speed - 1 Bit Defines Two Speed Classes as Allowed Under SPCDS Specification

   Failed Self Test - 7 Bits
   a. Acknowledge Self Test Initiate - 1 Bit
   b. Failed Sensor Numbers - 7 Bits

   Tamper Report
   a. Tampered Sensor Number - 7 Bits
   b. Transmission Line Tamper (CMSD to RDD) - 1 Bit

   Line Fault
   a. Number of Failed Sensor - 7 Bits

5. Time - 17 Bits - Time of Occurrence of Report (One Second Resolution in 24 Hour Day)

6. ORC Location - 22 Bits
   a. First Priority: Location of Sensor in Cartesian Coordinates - 22 Bits (10 m Accuracy)
   b. Second Priority: Area ID, Transmitter ID

7. Parity Check - 1 Bit - Even or Odd Word Test

SPCDS DATA WORD

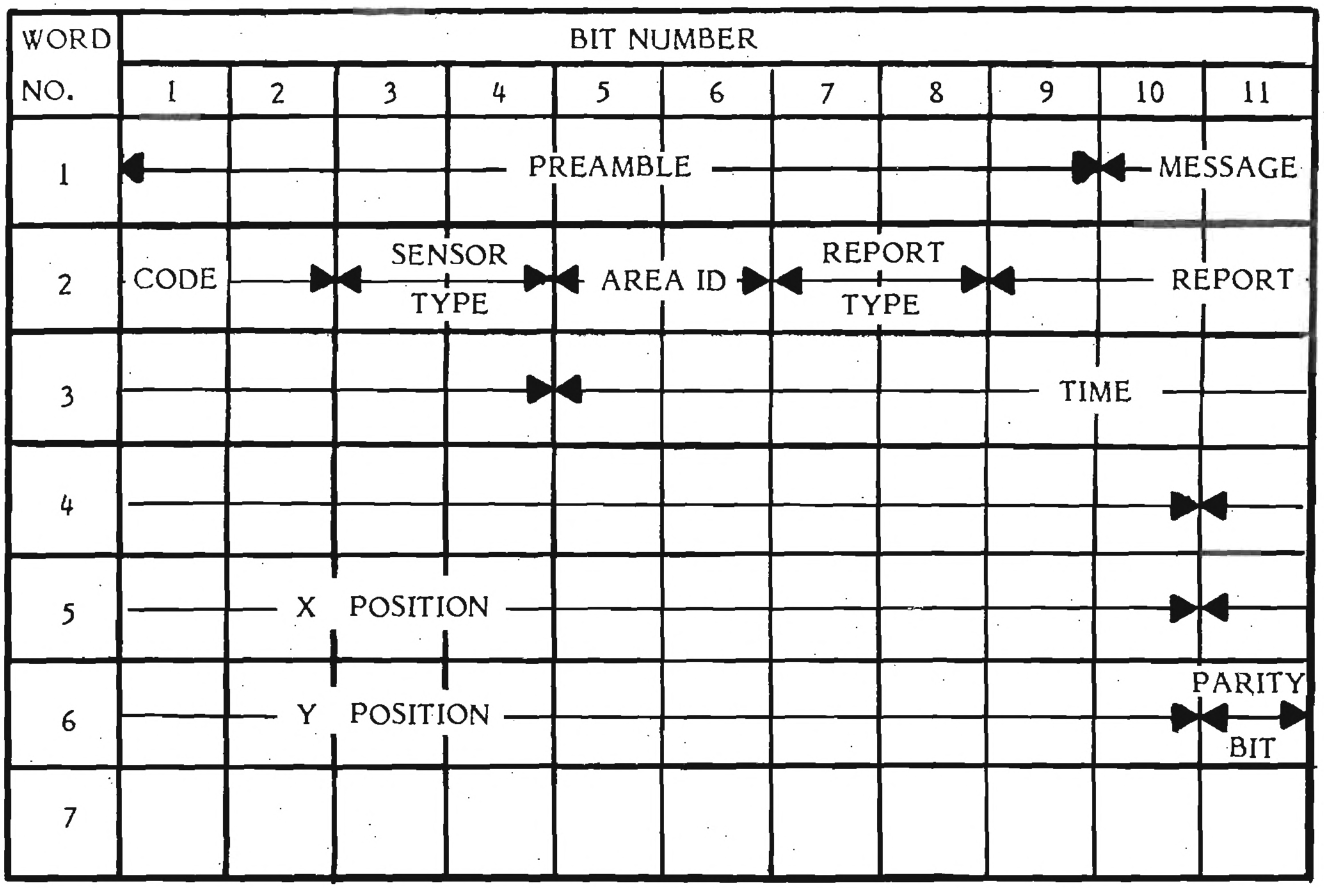


Figure B-10. SPCDS data word.

TABLE B-12. DEFINITION OF COMMAND WORD FOR SPCDS

1. Sensor Type - 2 Bits
   a. Radar
   b. SPCDS
   c. FIDS
   d. REAMBASS

2. CMSD ID - 2 Bits Identifies One of Four CMSD Units

3. Command Subclass - 1 Bit
   a. Initiate Self Test
   b. Set Time

4. Time Refrence - 17 Bits Time Synchronization for Reference Clock in Interface

5. Parity Check - 1 Bit - Even or Odd Parity Check on Data Word

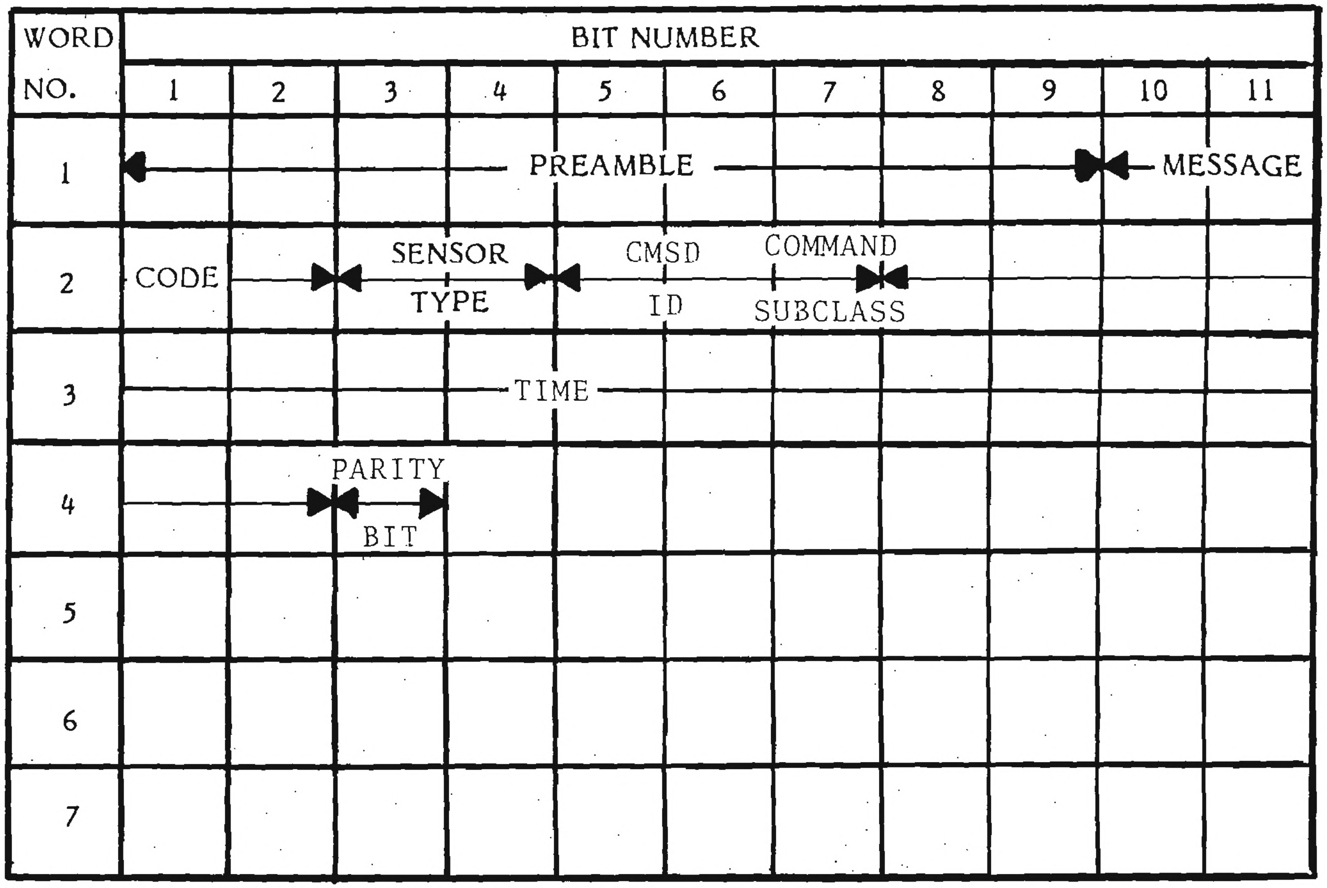


Figure B-11. SPCDS command word.

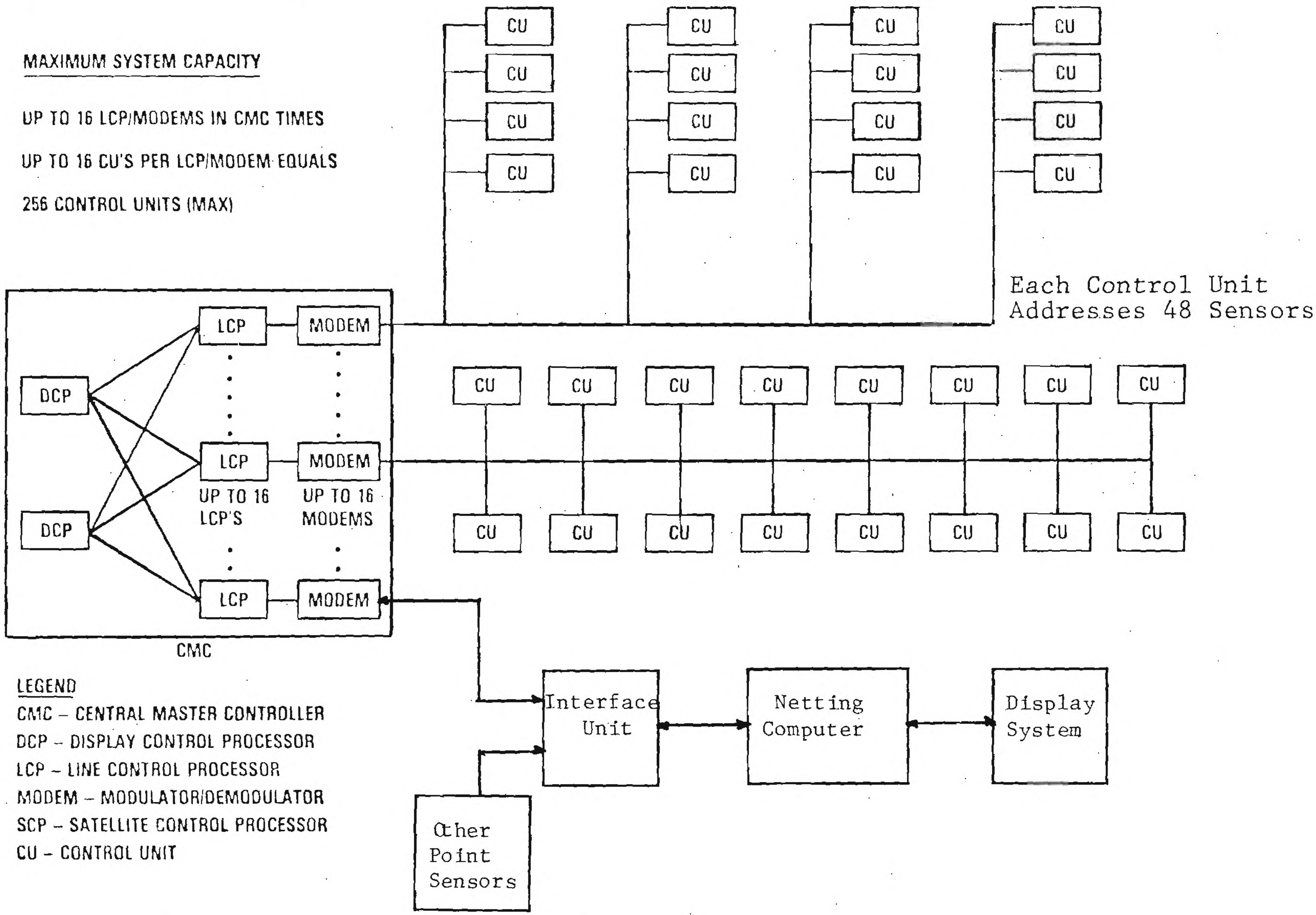


Figure B-12. Block diagram of netted interface to FIDS System.

control processors (LCPs) is replaced by an LCP emulator. Thus, the rest of the FIDS system operates normally, and all of the incoming data are available to the interface from the LCP buss. A code translator (probably a microprocessor) then translates the FIDS codes to the netted interface code.

Table B-13 gives the format for the FIDS data word. The word can be broken down into the sensor type, the line control processor ID, report category, report subclass (sensor alarm, built-in-test, tamper report, or self test response), time, sensor location, and parity bit. Figure B-13 shows the format for the data word; the format is very similar to that of the SPCDS system data word. Table B-14 gives the makeup of the FIDS command word. The FIDS system is capable of responding to several commands including deterrent initiate, self test initiate, entry allowance, and set time. The format for the command word is illustrated by Figure B-14; the structure is very similar to that for the SPCDS interface.

TABLE B-13. DEFINITION OF DATA WORD FOR FIDS

1. Sensor Type - 2 Bits
   a. Radar
   b. SPCDS
   c. FIDS
   d. REMBASS

2. Line Control Processor ID - 4 Bits - (Identifies One of 16 LCPs)

3. Report Catagory - 2 Bits
   a. Sensor Alarm
   b. Tamper Report Built in Test (BITE) Report
   c. Self Test Report

4. Report Subclass - 3 Bits
   a. Sensor Alarm - 3 Bits
      (1) Sensor Type
   b. Built in Test - 2 Bits
      (1) Type of Failure
   c. Tamper Report - 2 Bits
      (1) Physical Tampering
      (2) Proximity Detector
      (3) Link Check Failure
   d. Self Test - 2 Bits
      (1) Acknowledge Self Test Command
      (2) Self Test Complete
      (3) Component Failure
      (4) Degraded Performance

5. Time - 17 Bits - Time of Occurrence of Report (One Second Resolution in 24 Hours Day)

6. Sensor Location - 22 Bits
   a. First Priority: Cartesian Coordinates of Sensor Location (± 10 meters)
   b. Second Priority: Control Unit and Sensor Number (10 Bits)

7. Parity - 1 Bit - Even or Odd Data Word Check

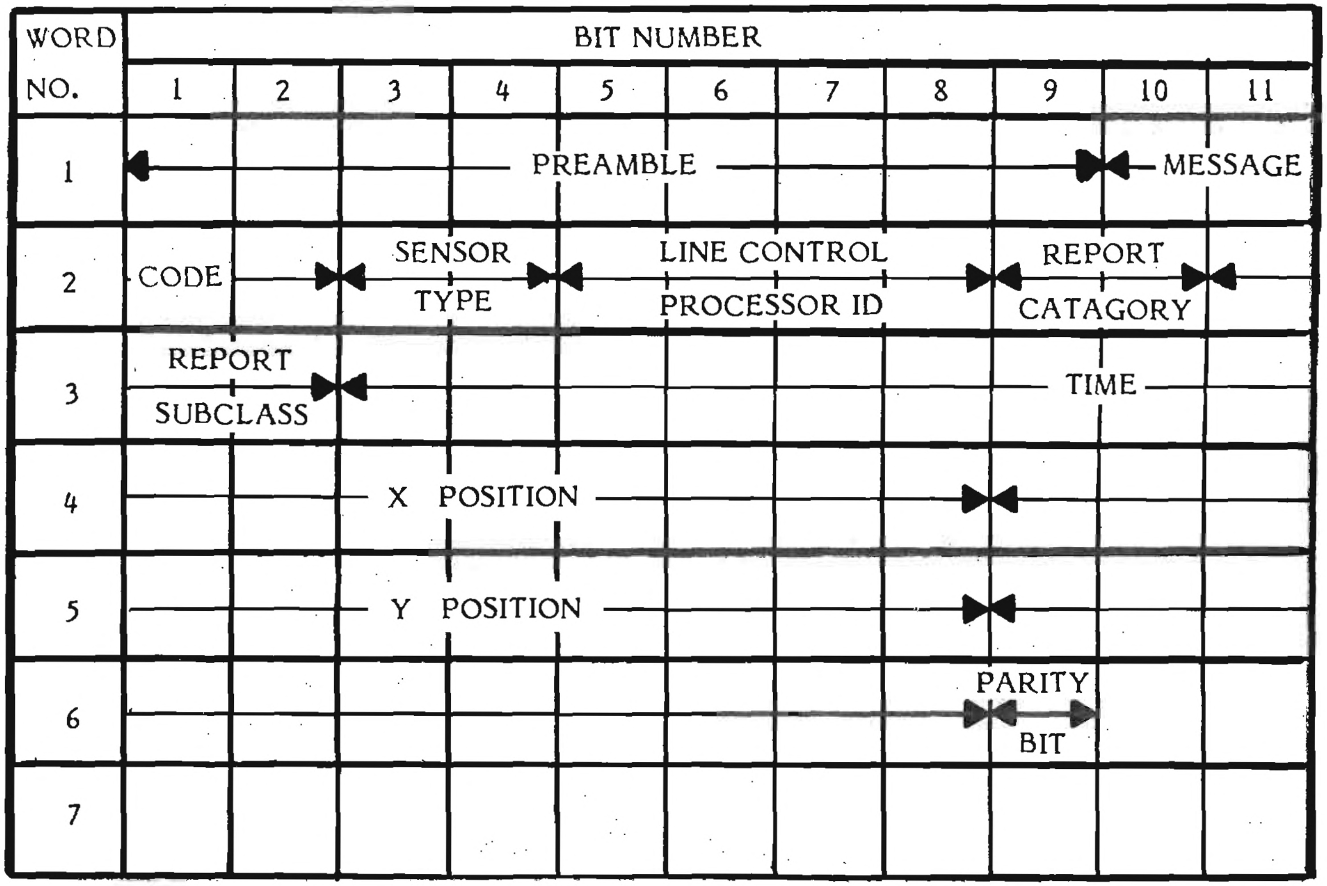


Figure B-13. Data Word for FIDS.

TABLE B-14. DEFINITION OF COMMAND WORD FOR FIDS

1. Line Control Processor ID - 4 Bits - Identifies One of 16 LCPs.

2. Command Class - Identifies Type of Command Message (2 Bits)
   a. Deterrent Command
   b. Initiate Self Test
   c. Entry Command
   d. Set Time

3. Command Subclass
   a. Deterrent Command - 2 Bits
   b. Initiate Self Test - 1 Bit
   c. Entry Command - 4 Bits
      (1) Shut Down Sensors - 2 Bits
      (2) Unlock Doors - 2 Bits
   d. Time - 17 Bits - Time to Nearest Second

4. Parity Check - 1 Bit

<table>
<tr><th rowspan="2">WORD NO.</th><th colspan="11">BIT NUMBER</th></tr>
<tr><th>1</th><th>2</th><th>3</th><th>4</th><th>5</th><th>6</th><th>7</th><th>8</th><th>9</th><th>10</th><th>11</th></tr>
<tr><td>1</td><td colspan="9">PREAMBLE</td><td colspan="2">MESSAGE</td></tr>
<tr><td>2</td><td colspan="2">CODE</td><td colspan="2">SENSOR TYPE</td><td colspan="4">LINE CONTROL PROCESSOR ID</td><td colspan="2">COMMAND SUBCLASS</td><td></td></tr>
<tr><td>3</td><td colspan="11">COMMAND SUBCLASS</td></tr>
<tr><td>4</td><td colspan="5"></td><td>PARITY BIT</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>5</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>6</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>7</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

Figure B-14. Command word for FIDS.

APPENDIX C

DISPLAY TECHNOLOGY SURVEY

TABLE C-1. CANDIDATE DISPLAY SYSTEMS THAT USE STORAGE TUBE TECHNOLOGY

MANUFACTURER	MODEL	DATE INTRODUCED	RESOLUTION	NO. OF COLORS	K-BYTES TOTAL MEMORY	SUPPLIED SOFTWARE	AVAILABLE 1/0 DEVICES	OFF-LINE STORAGE	PRICE	REMARKS
Tektronix	4051, 4052	1973	11-in. storage tube; 1024 x 780	1	to 64K	Plot 10, TCS and IGL: graphics primitives, dynamic functions and applications	KBD, thumbwheel, tablet, joystick, plotters, video copiers	Cartridge-tape diskette	$6,295	Faster than 4010; 4052 is $9,900
	4054	4/79	19-in. storage tube; 4096 x 3125	1	to 64K	Plot 10, TCS and IGL: graphics primitives, dynamic functions and applications	KBD, thumbwheel, tablet, joystick, plotters, video copiers	Cartridge-tape diskette	$20,100	Continuous write-through optional
	4006	11/75	11-in. storage tube; 1024 x 780	1	No	Plot 10, TCS and IGL: graphics primitives, dynamic functions and applications	KBD, thumbwheel, tablet, joystick, plotters, video copiers	Cartridge tape	$3,600	Thumbwheel cursor control
	4010 - 4012, 4013	1975	11-in. storage tube; 1024 x 780	1	No	Plot 10, TCS and IGL: graphics primitives, dynamic functions and applications	KBD, thumbwheel, tablet, joystick, plotters, video copiers	Cartridge tape	$5,900	Thumbwheel cursor controls; 4012 adds lower-case characters; 4013 adds APL characters
	4014-1, 4015-1	1974	19-in. storage tube; 1024 x 780	1	to 32	Plot 10, TCS and IGL: graphics primitives, dynamic functions and applications	KBD, thumbwheel, tablet, joystick, plotters, video copiers	Cartridge-tape diskette	$1,475	Both units feature write-through; 4015 has APL characters for $16,900
	4016-1	6/78	25-in. storage tube; 4096 x 3120	1	to 32	Plot 10, TCS and IGL: graphics primitives, dynamic functions and applications	KBD, thumbwheel tablet, joystick plotters, video copiers	Cartridge-tape diskette	$18,000	Includes write-through
	4114	1980	19-in. storage tube; 4096 x 3120	1	to 800	Plot 10, TCS and IGL: graphics primitives, dynamic functions and applications	KBD, thumbwheel tablet, joystick plotters, video copiers	Cartridge-tape diskette	$17,500	Includes write-through

TABLE C-2. CANDIDATE DISPLAY SYSTEMS THAT USE STROKE REFRESH TECHNOLOGY

MANUFACTURER	MODEL	DATE INTRODUCED	RESOLUTION	NO. OF COLORS	K-BYTES TOTAL MEMORY	SUPPLIED SOFTWARE	AVAILABLE 1/0 DEVICES	OFF-LINE STORAGE	PRICE	REMARKS
Control Data	795 Digigraphic	2/80	21-in. stroke refresh; 1024 x 1024	1		Graphics primitives, dynamic functions	KDB, light pen	No	$25,000	Includes light pen for use with CDC computers
IMLAC	Series II	1980	19-in. stroke refresh; 2048 x 2048	1	64	Graphics primitives, dynamic functions	KBD, light pen, tablet, video copier	No	$15,750	Storage-tube emulation is available
Megatek	Whizzard 7210		21-in. stroke refresh; 4096 x 4096	1-5	64-192	Wand 7200, graphics primitives, dynamic functions	KBD, joystick, tablet, matrix printer, screen camera	No	$25,000	Includes joystick; 5-color, 16-grey-shade beam-penetration terminal
Megatek	Whizzard 7290	5/81	21-in. stroke refresh; 4096 x 4096; and 21-in. raster; 512 x 512	1-5	64-192	Wand 7200, graphics primitives, dynamic functions	KBD, joystick, tablet, matrix printer, screen cameras	No	$40,000	Includes 1 stroke, 1 raster display, 2 KBDs, 2 joysticks
Sanders Associates	Graphic 7		21-in. stroke			CGL: graphics primitives, dynamic functions	KBD, light pen, tablet, matrix printer, screen cameras	No		
Vector Automation	Graphics 80	2/80	21-in. stroke refresh; 4096 x 4096	1	32-256	Graphics primitives, dynamic functions	KBD, light pen, tablet, joystick, video copier, matrix plotter	No	$24,500	

Notes:

1. Dynamic functions: zoom, pan, etc.
2. Virtually all have printer interfaces.
3. All prices include keyboard (KBD), standard display, graphics generator, BASIC software, interface, standard memory.

TABLE C-3. CANDIDATE DISPLAY SYSTEM THAT USE RASTER SCAN TECHNOLOGY

MANUFACTURER	MODEL	DATE INTRODUCED	RESOLUTION	NO. OF COLORS	K-BYTES TOTAL MEMORY	SUPPLIED SOFTWARE	AVAILABLE I/O DEVICES	OFF-LINE STORAGE	PRICE	REMARKS
Advanced Electronic Design	AED512	1980	13/19-in. raster; 512 x 512	256	32-256	Graphics primitives, dynamic functions	KBD, joystick, tablet, matrix printer, screen camera	Diskette, Winchester disk	$16,100	Includes 128K-byte RAM, joystick, firmware
Aydin Controls	5216	6/79	19-in. raster; 1024 x 1024	8	32-1000	Aygraf 2D, 3D graphics functions	KBD, joystick, light pen, trackball, matrix plotter	Cartridge-disk	$19,975	Includes 32K-byte RAM
	5217	1/79	13-in. raster; 720 x 480	8	4-32	Graphics characters	KBD, light pen	No	$2,995	For process control
BMC USA	IF-800/20 4013	1981	12-in. raster; 720 x 240	8		Charting functions, graphics characters	KBD, light pen, matrix printer	Diskette cartridge ROM	$6,950	Includes diskette drive, matrix printer
Calcomp	IGT-100	6/77	15-in. raster; 1024 x 680	1		Graphics primitives	KBD, tablet, matrix plotter		$13,500	
Chromatics	CG Series	6/79	13-, 15-, 19 in. raster; 512 x 512	8	96-132	Graphics primitives, dynamic functions	KBD, light pen, Xerox 6500 screen camera	Disk, diskette	$16,670	Includes 15-in. display, 132K-byte RAM, diskette drive
	CGC-7900	11/80	19-in. raster; 1024 x 768	8	128	Graphics primitives, dynamic functions	KBD, light pen, joystick	Disk, diskette	$14,995	Includes 128K-byte memory
Colorgraphic	MVI-7	8/81	13-, 15-in. raster; 720 x 288	8	Refresh only	Graphics primitives	KBD, light pen	No	$3,500	Extra memory needed for circle and ARC generation
Data General	Dasher D280C	8/81	13-in. raster; 560 x 240	8		Graphics primitives	KBD	No	$3,805	
	Dasher G300	3/81	12-in. raster; 640 x 240	1		Trendview business package, graphics primitives	KBD, matrix printer	No	$7,400	Emulates Dasher D200

TABLE C-3. CANDIDATE DISPLAY SYSTEMS THAT USE RASTER SCAN TECHNOLOGY (CONTINUED)

MANUFACTURER	MODEL	DATE INTRODUCED	RESOLUTION	NO. OF COLORS	K-BYTES TOTAL MEMORY	SUPPLIED SOFTWARE	AVAILABLE I/O DEVICES	OFF-LINE STORAGE	PRICE	REMARKS
Datamedia	Colorscan 10	1981	12-in. raster; 640 x 240	8		Charting functions, graphics primitives	KBD	No	$3,795	A DEC VT-100/VT-52 emulator
Datapoint	9680	11/81	13-in. raster; 512 x 480	16	128-156	Business functions, graphics primitives	KBD, tablet, matrix printer, screen camera	No	$30,000	Includes tablet instead of KBD STD for use with Datapoint ARC Systems
Digital Equipment	GIGI	5/81		8		Graphics primitives	KBD tablet, printer	No	$5,000	User must provide display monitor
	VS11 Series	5/80	19-in. raster; 512 x 512	16	Refresh only	Graphics primitives	KBD, joystick	Diskette, disk, magnetic tape	$13,600	Includes joystick for use with DEC systems
DY-4 Systems	VGT-100	in production	15-in. raster; 640 x 240	1		Plot 10 - compatible	KBD, matrix printer	No	$2,988	
Genisco Computers	G-1000	8/80	19-in. raster; 1024 x 792	1	16	Plot 10 - compatible	KBD, light pen, matrix printer		$9,995	Emulates Tektronix 4010 with selective erase
	GCT-3000		Raster; 1280 x 1024	8			KBD, light pen, matrix printer		$14,550	
Hewlett-Packard	2623	1981	Raster; 512 x 390	1		Business graphics	KBD, thermal printer	No	$3,750	Integral thermal printer optional
	2647A	5/78	12-in. raster; 720 x 360	1	32	Business graphics, graphics primitives	KBD, pen, matrix plotters	Cartridge tape	$8,950	Functions as a stand-alone μC
	2648A	7/77	11-in. raster; 720 x 360	1	Refresh only	Business graphics, graphics primitives	KBD, pen, matrix plotters	Cartridge tape	$5,950	
Hitachi	H-7000	4/78	19-in. raster		7	256 graphics symbols	KBD, plotter	Diskette	$11,000	

TABLE C-3. CANDIDATE DISPLAY SYSTEMS THAT USE RASTER SCAN TECHNOLOGY (CONTINUED)

MANUFACTURER	MODEL	DATE INTRODUCED	RESOLUTION	NO. OF COLORS	K-BYTES TOTAL MEMORY	SUPPLIED SOFTWARE	AVAILABLE I/O DEVICES	OFF-LINE STORAGE	PRICE	REMARKS
HMW Data Systems	Data-color	1/81	14-in. raster; 480 x 240	27		Graphics characters	KBD, light pen	Diskette		
HMW Enterprises	9001-IGT	7/79	13-in. raster; 640 x 288	8	8	Graphics primitives	KBD, light pen, joystick, trackball, matrix printer, video copier	Disk	$10,000	OEM (quantity 100) price
Human Designed	Concept Series	1978	12-in. raster; 264 x 72	1	Refresh only	Graphics characters	KBD	No	$1,575	APL KDB optional
IBM	3279	10/79	14-in. raster; 760 x 384	7		Graphics primitives	KBD, matrix printer	No	$3,805	
Industrial Data Terminals	IDT-1800	9/80	19-in. raster; 512 x 256	8	Refresh only	Graphics primitives, macrographics	KBD, light pen, matrix printer	No	$7,490	
	IDT-2000	3/80	19-in. raster; 512 x 512	8	Refresh only	Graphics primitives, macrographics	KBD, light pen, matrix printer	No	$10,600	
	IDT-2200	7/81	19-in. raster; 512 x 512	8	Refresh only	Graphics primitives, macrographics	KBD, light pen, matrix printer	Bubble Memory	$11,495	
Integrated Data Systems	ID-400	5/79	13-in. raster	16	2	Graphics characters	KBD	No	$2,855	OEM (quantity 25) price
	ID-800 Series	7/81	13-, 19-in. raster	16	2	Graphics characters	KBD	No	$2,090	OEM (quantity 25) price; 19-in. version, $3,075
	ID-212	7/81	12-in. raster	16	2	Graphics characters	KBD	No	$1,695	OEM (quantity 25) price
	ID-1200	1/82	13-, 19-in. raster	16	4-128	Graphics characters CP/M, BASIC	KBD	No	$2,485	OEM (quantity 25) price, 19-in. version, $3,395; functions as stand-alone C

TABLE C-3. CANDIDATE DISPLAY SYSTEMS THAT USE RASTER SCAN TECHNOLOGY (CONTINUED)

MANUFACTURER	MODEL	DATE INTRODUCED	RESOLUTION	NO. OF COLORS	K-BYTES TOTAL MEMORY	SUPPLIED SOFTWARE	AVAILABLE I/O DEVICES	OFF-LINE STORAGE	PRICE	REMARKS
Integrated Terminals	801	8/81	12-in. raster; 160 x 96	8	6-10	Graphics characters	KBD, light pen	No	$3,000	
Intelligent Systems Corp.	3600	10/80	13-in raster; 128 x 128	8	8-32	Chart graphics, graphics primitives	KBD, matrix printer	Diskette	$1,995	
	8001G	1973	19-in. raster; 192 x 160	8	13	Chart graphics, graphics primitives	KBD, matrix printer	Diskette	$2,745	$2,120 cash in advance
	8001L	11/80	19-in. raster; 480 x 384	4319	96	Chart graphics, graphics primitives	KBD, matrix printer	Diskette	$4,460	$3,695 cash in advance
	8300	10/80	13-in. raster; 192 x 160	8	8-64	Chart graphics, primitives graphics	KBD, matrix printer	Diskette	$3,560	
Lexicon	Lexiscope 4000	1981	Raster; 560 x 500	1		DG, HP commands	KBD	No	$3,240	Includes light pen; designed for use with Data General computers
Matrox Electronics	CTM-300	6/81	12-in. raster	8	2	Graphics characters, graphics primitives	KBD	No	$2,940	
Megatek	Whizzard 6240	1979	19-in. raster; 512 x 512	1	64-128	Wand 6200, graphics primitives, dynamic functions	KBD, joystick, tablet, matrix printer, screen camera	No	$14,900	Includes joystick, 64K-byte RAM
	Whizzard 6245	1980	19-in. raster; 1024 x 1024	1	64-128	Wand 6200, graphics primitives, dynamic functions	KBD, joystick, tablet, matrix printer, screen camera	No	$17,900	Includes joystick, 64K-byte RAM

TABLE C-3. CANDIDATE DISPLAY SYSTEMS THAT USE RASTER SCAN TECHNOLOGY (CONTINUED)

MANUFACTURER	MODEL	DATE INTRODUCED	RESOLUTION	NO. OF COLORS	K-BYTES TOTAL MEMORY	SUPPLIED SOFTWARE	AVAILABLE I/O DEVICES	OFF-LINE STORAGE	PRICE	REMARKS
	Whizzard 6250	1979	13-in. raster; 512 x 480	1	64-128	Wand 6200, graphics primitives, dynamic functions	KBD, joystick, tablet, matrix printer, screen camera	No	$17,500	Includes joystick, 64K-byte RAM
	Whizzard 6255	1980	19-in. raster; 1024 x 1024	8	64-128	Wand 6200, graphics primitives, dynamic functions	KBD, joystick, tablet, matrix printer, screen camera	No	$31,500	Includes joystick, 64K-byte RAM
Megatek	Whizzard 7245	1980	19-in. raster; 1024 x 1024	1	64-192	Wand 7200, graphics primitives, dynamic functions	KBD, joystick, tablet, matrix printer, screen camera	No		Includes joystick
	Whizzard 7250	5/80	19-in. raster; 512 x 512	16	64-192	Wand 7200, graphics primitives, dynamic functions	KBD, joystick, tablet, matrix printer, screen camera	No	$35,000	Includes joystick, 128K-byte RAM
	Whizzard 7255	5/80	19-in. raster; 1024 x 1024	16	64-192	Wand 7200, graphics primitives, dyanmic functions	KBD, joystick, tablet, matrix printer, screen camera	No	$60,300	Includes joystick, 128K-byte RAM
MQI Computer	Autograph 150		12-in. raster; 512 x 250	1		Graphics primitives	KBD	No	$2,590	
North Star Computers	Advantage		12-in. raster; 640 x 240	1	84	Graphics primitives, dynamic functions, CP/M	KBD, matrix printers	Dual diskettes		Stand-alone μC including diskettes

TABLE C-3. CANDIDATE DISPLAY SYSTEMS THAT USE RASTER SCAN TECHNOLOGY (CONTINUED)

MANUFACTURER	MODEL	DATE INTRODUCED	RESOLUTION	NO. OF COLORS	K-BYTES TOTAL MEMORY	SUPPLIED SOFTWARE	AVAILABLE 1/0 DEVICES	OFF-LINE STORAGE	PRICE	REMARKS
Ramtek	6211	6/81	13-in. raster; 640 x 512	16	46-58	CGL: graphics primtives, dynamic functions	KBD, light pen, tablet, matrix printer, screen camera	No	$5,995	Desk-top terminal
	6212	1980	13-in. raster; 640 x 512	16	46-58	CGL: graphics, primitives, dynamic functions	KBD, light pen, tablet, matrix printer, screen camera	No	$10,000	Expandable modular terminal
SCION	Microangelo		15-in. raster; 512 x 480	256		Graphics			$2,495	
SRA Communications	SEMIGRAF 240	6/78	13-in. raster; 512 x 256	8		Graphics characters, curve generator	KBD	Diskette		
Tektronix	4025A	11/77	12-in. raster; 640 x 462	1	to 64	Plot 10, TCS and IGL: graphics primitives, dynamic functions and applications	KBD, thumbwheel tablet, joystick, plotters, video copiers	Cartridge-tape diskette	$5,200	
	4027A	6/78	13-in. raster; 640 x 462	8	to 224	Plot 10, TCS and IGL: graphics primitives, dynamic functions and applications	KBD, thumbwheel tablet, joystick plotters, video copiers	Cartridge-tape diskette	$10,000	
	4112	1980	15-in. raster; 640 x 480	1	to 672	Plot 10, TCS and IGL: graphics primitives, dynamic functions and applications	KBD thumbwheel, tablet, joystick plotters, video copiers	Cartridge-tape diskette	$9,600	

TABLE C-3. CANDIDATE DISPLAY SYSTEMS THAT USE RASTER SCAN TECHNOLOGY (CONTINUED)

MANUFACTURER	MODEL	DATE INTRODUCED	RESOLUTION	NO. OF COLORS	K-BYTES TOTAL MEMORY	SUPPLIED SOFTWARE	AVAILABLE 1/0 DEVICES	OFF-LINE STORAGE	PRICE	REMARKS
	4113	1981	19-in. raster	8-16		Plot 10, TCS and IGL: graphics primitives, dynamic functions and applications	KBD, thumbwheel tablet, joystick plotters, video copiers	Cartridge-tape diskette	$16,500	Includes diskettes
Tele-crafters	CDT-7001	6/80	13-in. raster; 512 x 256	8	8	Graphics characters, graphics primitives	KBD	No	$6,600	Extended graphics optional
	MCD 4001B	1979	13-in. raster; 512 x 256	8	4	Graphics characters, graphics primitives	KBD, joystick, light pen, track-ball, matrix printer	Diskette	$7,500	Extended graphics option, $5,000
Terak	8510/A	1981	12-in. raster; 320 x 240	1	64	Graphics primitives, dynamic functions	KBD	Diskette	$8,350	Includes diskette
	8600	1981	13-in. raster; 40 x 480	64		Graphics primitives, dynamic functions	KBD, joystick, DEC-compatible printers	No	$16,500	
TRW-Fijitsu	Facom 9430	9/81	14-in. raster; 1024 x 800	1-8	128	Tektronix 4012-compatible	KBD, light pen, thermal printer	Diskette	$7,490	Includes light pen; optional color display is 512 x 400

TABLE C-4. CANDIDATE DISPLAY SYSTEMS THAT USE PLASMA DISPLAY PANEL OR LIGHT EMITTING DIODE TECHNOLOGY

MANUFACTURER	MODEL	DATE INTRODUCED	RESOLUTION	NO. OF COLORS	K-BYTES TOTAL MEMORY	SUPPLIED SOFTWARE	AVAILABLE 1/0 DEVICES	OFF-LINE STORAGE	PRICE	REMARKS
Interstate Electronics	PD Series	1980	12-in. plasma; 512 x 512	1	64	Graphics primitives	Touch panel, joystick	Diskette		
Litton Data Systems	Brief case terminal	1980	LED panel 4.5"H x 12'W (144 x 384 diodes)	1	384	Graphics capability when used with digitizer	Digitizer, type-writer keyboard, and printer	Magnetic tape or floppy disk		Z-800 - 16 bit central processor with 256K-bytes for high speed processing. (4) NSC 800S, for display maintenance, graphics, etc. 9 and 24 volt D.C. operation.
	Tactical display system	1981	3 sizes available. Advertised screen size 28.8"H x 22.4"W 20 lines per inch 3 color LED	3		Military symbols, also alphanumerics	112 function switches with pre-programmed instruction recall			Display stand alone capa-bilities not described in literature

APPENDIX D
AN/PPS-15(B) INTERFACE DESIGN

D.1 OVERVIEW

General descriptions of currently available radar and non-radar physical security sensors are given in Appendix A, and generalized interface requirements to a netted system for each sensor class are described in Appendix B. In this Appendix, a more detailed description will be given of two methods of implementing the AN/PPS-15(B) into a netted system: one method involves utilization of most of the current AN/PPS-15(B) signal processing and timing circuits, but yielding lower performance; the other method involves replacing most of the AN/PPS-15(B) with automated computer hardware which yields much higher performance (at higher cost).

Security systems using large numbers of fixed location sensors connected to a central monitoring console have demonstrated the efficient and effective manner that security guards may monitor and evaluate intrusion threats to secure areas. Two fixed-location netted sensor systems achieving this function are discussed in this report. The advantages and feasibility of combining the intrusion data from one or more surveillance radar sensors into a common display have also been proven through field tests against simulated targets (as described in the discussion of the LARIAT netted radar system in this report). The potential advantages of extending this netting concept to include inputs from both fixed-location sensors systems and radars have been identified, and concepts have been defined for specifying the hardware and software algorithms to accomplish these designs. A communication format capable of supporting the proposed netting concept is described in Appendix B of this report. This interface description is compatible with established data-line system requirements as outlined in SEIWIG-005.

The addition of a radar sensor unit (or units) to a net of fixed-location sensors allows intruding targets to be monitored via multiple sensor technologies potentially providing advanced verification techniques that may improve the overall detection and false alarm characteristics of the netted surveillance system. Three candidate radar systems were included in the netting study described in this report. These three radar systems (the AN/PPS-5, the AN/PPS-15 or 15(B), and the FOLPEN) represent current state-of-the-art surveillance systems that have operating characteristics addressing the problems for (1) large area surveillance requirements, (2) moderate range sector coverage or "gap-filler" applications, and (3) base areas requiring moderate amounts of foliage penetration. The AN/PPS-5 Modified radar set was used in the LARIAT netted radar feasibility demonstration for the MX missile system. While this modified radar has many desirable characteristics of a moderate-to-long range ground surveillance radar, it is not currently available in the military inventory and no future development of this capability is anticipated.

The FOLPEN radar is being designed to meet the special requirements involved in surveillance of base areas containing heavy foliage where conventional radar sets will not penetrate. However, this system is still experimental and in a developmental state. The definition of a data-link interface for this radar is not complete at this time due to the developmental state of this system. Furthermore, this unit may have only limited use in the netting security/surveillance field since it is primarily intended for searching foliated areas. Due to the low operating frequency required for this application, only a limited number of FOLPEN radars can be used in a given area without expecting interference problems between radar units and with nearby communication and television services.

The most promising radar examined for the near-term solution to the radar surveillance problem is the AN/PPS-15(B) or its proposed predecessor the (EPSD). While the AN/PPS-15(B) radar set operates as a sector-scan device with a detection range limited to about 3 kilometers (for a 10 square meter radar cross-section target i.e., a vehicle size target), it possesses many capabilities that are desirable in a radar sensor for a netted surveillance system. Unfortunately, neither the model "B" or the proposed EPSD follow-on has an adequate data-link interface to effectively meet the present and future requirements for the proposed netting concept with fixed-location sensor systems and/or with other radar systems.

The AN/PPS-15(B) radar set will be used in this section as an example of the techniques required to adequately interface a complex sensor unit into the proposed netting configuration defined in this report. Two proposed interface descriptions are included for this purpose that will modify the AN/PPS-15(B) radar to provide (1) a partially implemented radar surveillance system using the seven range bins currently instrumented or (2) a fully implemented radar system instrumenting all available range bin positions. These proposed system modifications are a suitable departure point for obtaining an effective ground surveillance radar sensor in the reasonably near future that is truly usable in a netted configuration with other sensor technologies and/or other radars. A hardware demonstration of the feasibility of the proposed modifications could potentially shorten the development time required to field the combined capability surveillance system described in this report.

D.2 DESIGN PHILOSOPHY

Many design aspects for applying radar sensors to netted surveillance systems have been outlined in previous sections of this report. A block diagram of this netted surveillance system concept is given in Figure D-1. Three sector-scan radar sets are indicated in this illustrative example to scan areas adjacent to protected high-risk assets within a defended base area that also contains a network of fixed-location sensors. Target information from these surveillance radars is processed within the netting computer facility to combine all target information into a common display for the monitoring operator. The design philosophy for the netted surveillance system should allow intruding targets to be monitored via multiple sensor technologies in order to utilize advanced verification techniques to improve the overall detection and false alarm characteristics of the netted system. The netted system should be designed to provide operator assistance in the form of:

1. Automatic operation of the equipment,
2. Automatic status checking of the system components and this operation,
3. Automatic target detection and tracking,
4. Threat evaluation of detected targets (either automatically or as designated by the operator), and
5. Combine multiple sensor information (radar and fixed location sensors) into a common scenario-map presentation.

These netted surveillance system guidelines drive the design of the radar interface and the sensor unit. Basic to the system netting philosophy is the demonstrated concept of reporting detected targets (or suspected targets) with the minimum information of position and time of detection. This minimizes the bandwidth requirements for the data link, but assumes a preprocessing capability at the sensor unit. The simplified information of location and detection time proved adequate for the automatic detection, tracking, and threat evaluation algorithms used in the feasibility demonstration of the LARIAT netted radar system. Additional information obtained from the radar or sensor preprocessor (such as target speed, direction, classification, etc.) can be used to enhance the basic sensor netting algorithms with little modification. The data link interface should accommodate a reasonable expansion of the data to include foreseeable requirements in this area. The radar interface description in Appendix B of this report accommodates this design philosophy.

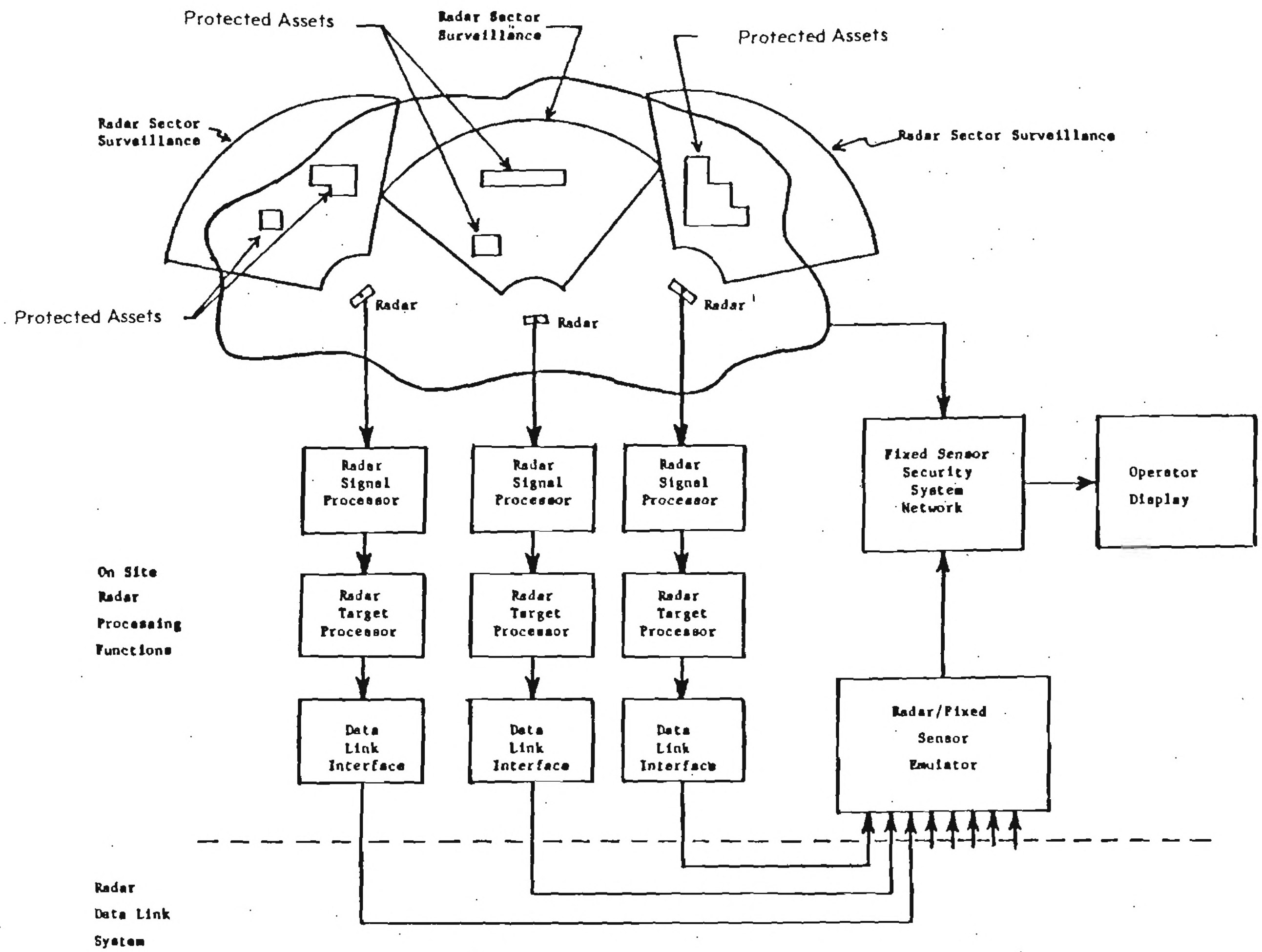


Figure D-1. Netted radar/fixed location sensor surveillance scenario.

D.2.1 RADAR TARGET DETECTION/TRACKING ALGORITHMS

There are three basic algorithm concepts for radar target processing. The most simple of these is the Area Alarm Mode. This detects and reports targets within a single radar resolution surveillance sector. While having a minimum of instrumentation and preprocessing requirements, this algorithm concept represents a fairly inefficient use of the surveillance of the radar system. This concept is not adaptable to the netting concept defined in this report since the location information is not available for the proposed tracking algorithms.

A second basic concept detects and tracks single targets in a Sector Search/Azimuth Track Mode. This provides position information on detected targets, but can not handle multiple simultaneous targets. This basic operating mode is very helpful to the radar system that is continuously monitored by a dedicated radar operator, but is considered too restricted to be effective in a netted surveillance system.

A Track-While-Scan Mode provides both range and azimuth information on multiple targets and offers a more efficient use of the capabilities of the radar set. This approach can provide positional information on several targets simultaneously within the surveillance sector of the radar. This processing is desirable for netting applications using the small sector radar as well as for applications requiring an area radar system. The proposed detection/tracking algorithms are equally usable for (1) automatic monitoring of a single radar, (2) combining the surveillance capabilities of a single radar with a conventional fixed location sensor system, or (3) combining the surveillance capability of a number of radars into a single security system with or without a fixed location sensor capability. The concepts proposed here are intended to allow maximum flexibility in the surveillance sensor mix to match the actual base and threat scenario requirements.

D.2.2 PRELIMINARY CONCLUSIONS

The initial analysis of the radar sensors indicates that a track-while-scan radar surveillance concept offers the most efficient use of the radar's surveillance capabilities. The AN/PPS-15(B) is the most promising near-term solution for a nettable radar surveillance system. However, this unit does not have the required interface for netting in the current production model or in any known follow-on configuration. One improvement included in the "B" model is a signal processing system that can simultaneously monitor radar returns from seven range bins. While this can represent a significant surveillance area with a reasonable scan sector, it does not utilize the full surveillance capability of the radar.

D.2.3 SURVEILLANCE RADAR OPTIONS

As a direct result of these preliminary conclusions, two options were defined for accomplishing the goals of the design philosophy of interfacing the AN/PPS-15(B) radar in a netted surveillace system. Either of these two proposed modifications should produce a nettable ground surveillance radar in a cost effective manner. A block diagram showing the basic system components of the AN/PPS-15(B) radar is shown in Figure D-2. The "B" model includes the Multiple Range Gate (MRG) Unit that contains the signal processor for the seven range bins.

The first modification option makes maximum use of the current signal processing system in the AN/PPS-15(B) radar set. This approach can lead to a partial implementation of a track-while-scan surveillance system by interfacing the netted system data-link with the MRG unit to utilize the seven range bins included with this model design. The second modification option defines an alternate signal processor design for the AN/PPS-15(B) radar that allows the full surveillance capability of the radar set to be utilized when this unit is connected in a netted surveillance/security system. The first option is considered a candidate for retrofit modification of existing radar units while the second option is considered to be a large enough change to be considered as a future model design.

D.2.3.1 Partial Implementation/Track-While-Scan Option

The first modification option to the AN/PPS-15(B) radar is a partial implementation of the track-while-scan concept. This modification to the radar system is outlined in the block diagram in Figure D-3. The driving element in this design is the Data Link Interface Unit that performs the task of providing a two-way interface between the radar system and the remote netting computer. The requirements for this Input-Output (I/O) interface can be met by a serial format that allows transmission of the digital information over conventional radio or hardwired data-links. The formatting of the data from the radar set before transmission can be accomplished by a simple microprocessor located at the radar set.

The proposed modifications to the radar set are indicated in the block diagram as being separated from the radar elements by the dashed line. While the elements effecting this modification are shown apart from the radar in this block diagram, they

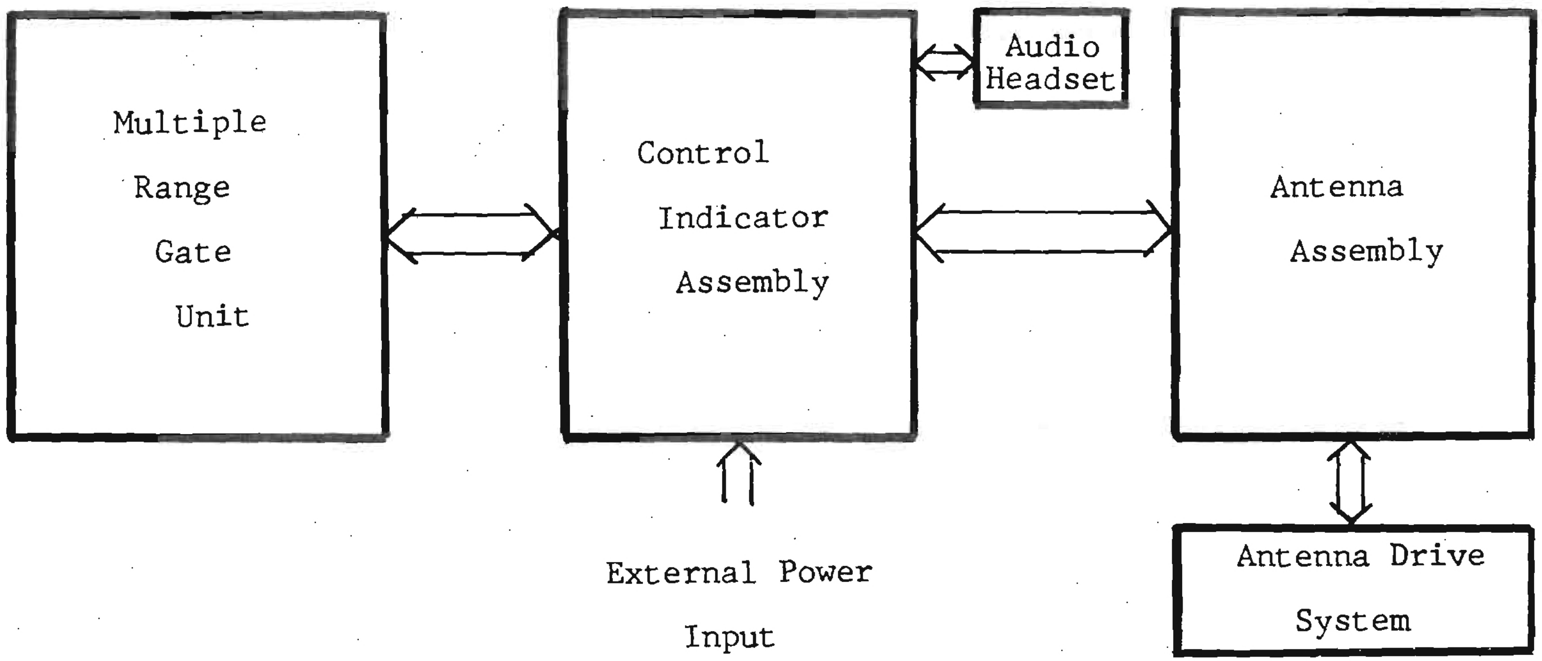


Figure D-2. Basic system components of the AN/PPS-15(B) radar system.

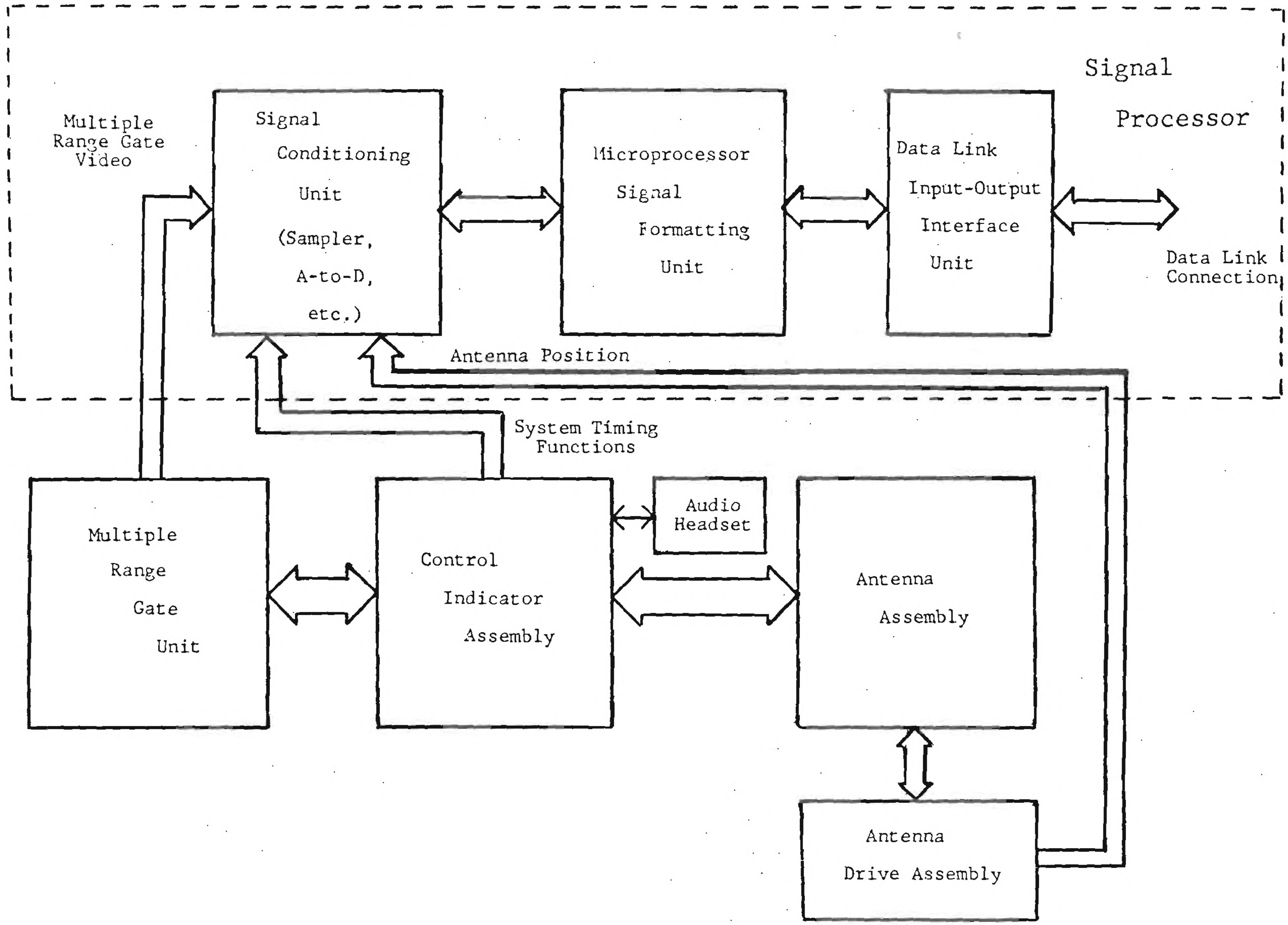


Figure D-3. Block diagram of proposed partially implemented netting interface (seven range bins) for AN/PPS-15(B) radar.

will be located at or in the radar set to provide the required signal preprocessing. The signal flow in Figure D-3 shows three types of signals going from the radar unit to the Netting Preprocessor/I-O Interface. These signals include (1) the system timing functions, (2) the Multiple Range Gate "video" (or the detected outputs), and (3) the azimuth position or pointing angle of the radar antenna. One important point in this block diagram is the signal flow between the radar set and the Netting Preprocessor/I-O Interface is only in one direction. **It is not proposed to change the normal operation of the radar.**

The key to understanding the signal preprocessing in this system modification lies in understanding the proposed communication interface to the central netting computer. A detail description of this interface is given in Appendix B of this report. The discussion of the Netted Interface For Short Range Sector Radars in this appendix applies to this modification description. The two-way communication with the data-link is in the form of a 7-byte word (11 bits per byte). Digital communication over the data-link is made at a bit rate of 1200 baud as specified in the referenced SEIWIG-005. Definitions of the Command Word format (containing instructions and synchronization signals to the radar set) and the Data Word format (containing the target and status reports from the radar sensor) are given in the referenced appendix. Tables D-1, D-2, and D-3 are repeated here to summarize the definitions of the Data Word and the Command Words as described in Appendix B. The Command Word is divided into two formats allowing an Initiatization Format to be used at system start up to initialize any parameters needed at the Netting Preprocessor/I-O Interface. Justification of the contents and resolution of these communication word formats are presented in the referenced appendix. The above discussion of the data-link interface is equally applicable to the second proposed modification to the radar (the fully implemented track-while-scan concept). Some of the capabilities specified in the communication word formats allows for future system expansion and are not fully utilized in this proposed radar modification.

Pedestal Interface Requirements. The pedestal operating requirements for both of the proposed modifications are identical. The basic conclusion included in both designs is that a track-while-scan radar makes the most efficient use of the surveillance capabilities of the radar. This requires that the antenna pointing system be restricted to operate only in the sector scan mode when the radar is part of a netted sensor surveillance system. The AUTO/MANUAL switch in the model B radar provides an automatic sector scan capability when placed in the AUTO position. This model provides

TABLE D-1. DEFINITION OF DATA WORD

1. Sensor Type - 2 bits -- defines 4 possible sensor types
   a. Radar
   b. SPCDS
   c. FIDS
   d. REMBASS
2. Radar ID - 3 bits -- identifies one of 8 possible radars in net
3. Report Category - 2 bits -- defines 4 radar report categories
   a. Occupied Resolution Cell (ORC) Report
   b. Built In Test (BIT) Failure Report
   c. Tamper Report
   d. Self Test Report
4. Report Subclass - 5 bits -- identifies report type under above categories or velocity information for ORC Report
   a. ORC Report
      (1) Speed - 4 bits defines ORC velocity category or velocity bin number
      (2) ORC Direction - 1 bit - defines in/out direction of ORC modem
   b. BIT Report
      (1) Equipment Failure
      (2) Degraded Performance
   c. Tamper Report
      (1) Physical Tampering/Equipment Entry
      (2) Electromagnetic Countermeasures (Jamming)
      (3) Proximity Detectors (Personnel nearby)
      (4) Sensor Moved (detects possible change in pointing direction)
   d. Self Test
      (1) Acknowledge Self Test Request
      (2) Self Test Completed - System OK
      (3) Equipment Failure
      (4) Degraded Performance

TABLE D-1. DEFINITION OF DATA WORD (Continued)

e. Communication

(1) Link Check

5. Time - 17 bits -- time of occurrence of report (one second resolution in 24 hour day)

6. ORC Location

a. First Priority: Cartesian Coordinates - 22 bits

b. Second Priority: Polar Coordinates - 13 bits

7. Parity - 1 bit -- An even or odd parity check on data word

TABLE D-2. DEFINITION OF COMMAND WORD

1. Radar ID - 3 bits -- Identifies one of 8 possible radars in net.

2. Command Subclass - 2 bits -- Defines type of Command Message.

3. Direction of Scan Center - 11 bits -- Defines pointing direction of sector center with a resolution of 0.2 degrees over a range of 360 degrees.

4. Width of Scan Sector - 6 bits -- Defines sector width with a resolution of 5 degrees over a maximum sector width of 180 degrees.

5. Range Bin Position - 10 bits -- Defines position of reference bin (for example: inner range bin) from radar with a resolution of 5 meters over a maximum range of 4 kilometers.

6. Distance Between Range Bins - 3 bits -- Defines separation of adjacent range bins (For example: the EPSD has two range bin separation distances - 50 meters and 500 meters).

7. Time - 17 bits -- Time synchronization for reference clock in radar.

8. Operating Mode - 4 bits -- Defines the operating mode of the radar. This quantity is specific to each radar system design (For example: the EPSD may operate in the Search or Track Mode). First Mode Bit defines Manual/Computer Control of radar.

9. Radar Location - 22 bits -- Initializes the radar signal processor with the coordinates of the radar set.

10. Self Test Initiate - 2 bits -- Initiates Self Test routines designed into the surveillance radars. (Includes a Communication/Data Link Test).

11. Clutter Filter Cutoff Frequency - 3 bits -- Controls possible settings of the clutter rejection filter.

12. Parity Check - 1 bit -- An even or odd parity check on the data word.

TABLE D-3. AN/PPS-15(B) SIGNAL PROCESSING HIERARCHY

A. Radar preamplifier output processed in delay-line processor to form discrete range video.

B. Gain controlled amplifier used as Sensitivity Time Control (STC).

C. Range gate hold-off waveform used to blank ranges not being processed.

D. CMOS analog sampling switches gate return radar signal into 7 separate processing channels.

E. Storage capacitor holding-circuits used in each channel to:
   1. "Stretch" or "hold" analog sample for duration of time between samples.
   2. Form part of high-pass/low-pass filter for each range-bin channel.

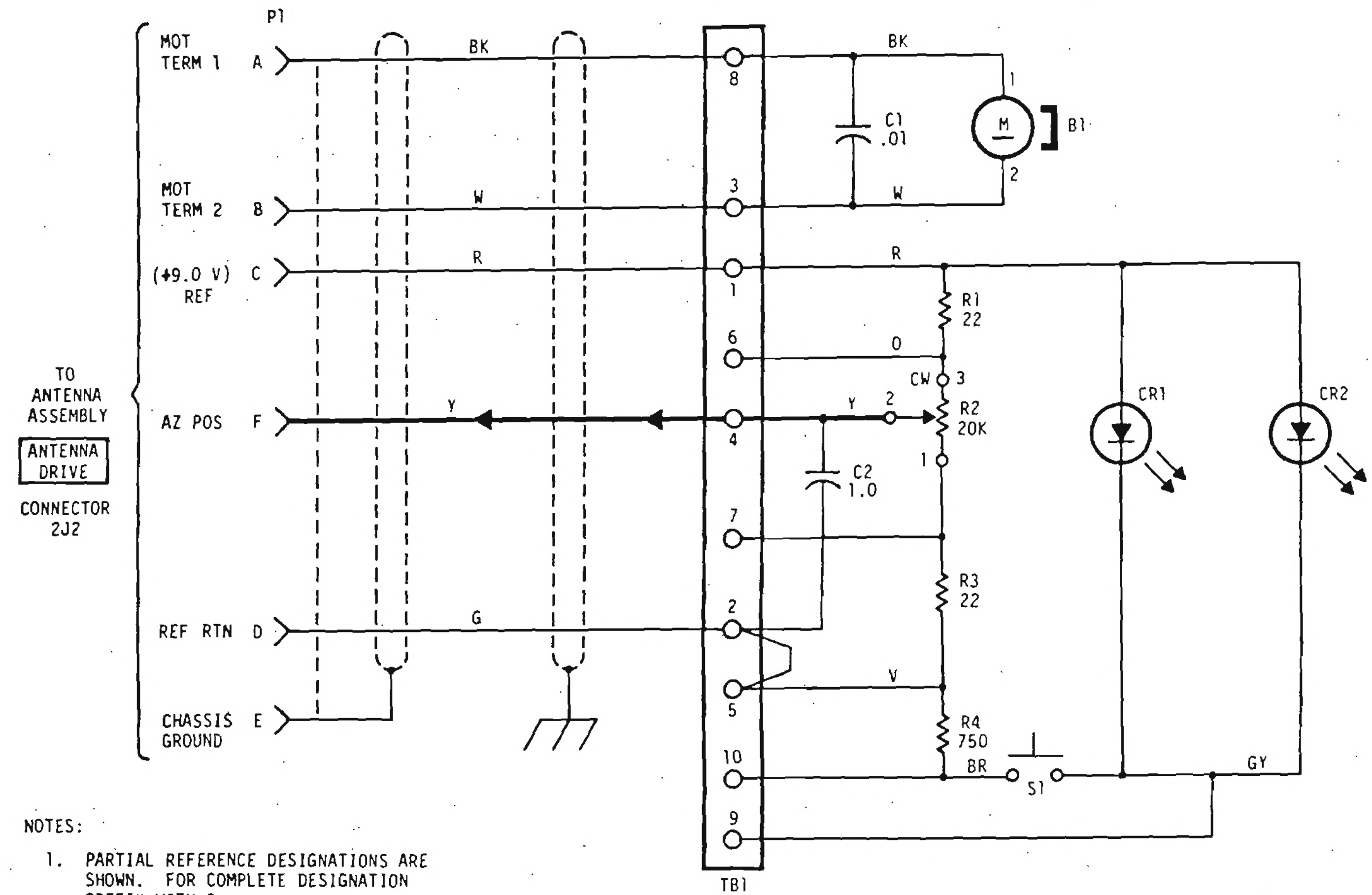
F. Range gated signals synchronously detected using all-range Doppler as the coherent reference to detect high-speed and low-speed targets (parallel channels).

G. Integrated output of each range bin threshold-detected for target activity in that resolution cell.

a continuously variable sector scan width between 400 and 3200 mils (22.5 to 180 degrees) that is set by the SCAN WIDTH control on the radar. The azimuth position of the antenna is monitored by a potentiometer within the pedestal assembly. The center of the search sector can be changed electrically from the radar controls or by rotating the tripod-pedestal assembly. Electrical limits on the antenna scan angles exist within the pedestal control at 1400 and 5000 mils. The antenna positioning motor automatically reverses when these limits are reached. Mechanical stops are also included in this design to limit rotation at 1200 and 5200 mils should the electrical controls fail.

Attention must be taken during initial set up of the radar system to insure that the desired surveillance sector is within the allowable scanning angle of the antenna positioning system. Care should also be used in defining the sector width to be monitored since undesirably long scan times can be introduced by large surveillance sector widths. With a scan speed of 5 degrees per second, a 90 degree sector will have an average revisit time of approximately 18 seconds. If a dismounted intruder is walking at a nominal speed of 3 miles per hour, he would travel a distance of 24 meters during this average revisit time. This is the largest scan width that is recommended to insure that at least one detection is made while a walking target is passing through a given range bin. The problem of tracking moving vehicles is increasingly difficult as the target speed increases. The upper detection velocity (radial component) is limited to 45 miles per hour by the upper cut-off frequency in the signal processor of the radar set. Where tracking of vehicles is of primary importance, the sector scan width may be reduced (if practical) to decrease the revisit time of the radar beam. The target detection rate is also increased when overlapping coverage occurs from two or more radar sensors that are connected to a central netting computer.

The azimuth position of the antenna must be known in the preprocessing microcomputer at the radar unit. This requires two pieces of information: (1) an instantaneous measurement of the pointing direction of the antenna and (2) knowledge of the reference direction used in set-up and initialization of the radar sensor. The reference direction can be obtained by boresighting against a magnetic compass reference. The instantaneous pointing angle can be obtained by measuring the reference voltage on the potentiometer contained within the pedestal asembly. The azimuth position potentiometer is seen in the schematic diagram of the Antenna Drive Unit (Figure D-4) where pin F gives a voltage analog of the pointing position. The reference voltage across this potentiometer must also be known to make a meaningful determination of the pointing direction. These signals also appear on pins E, F, and H of



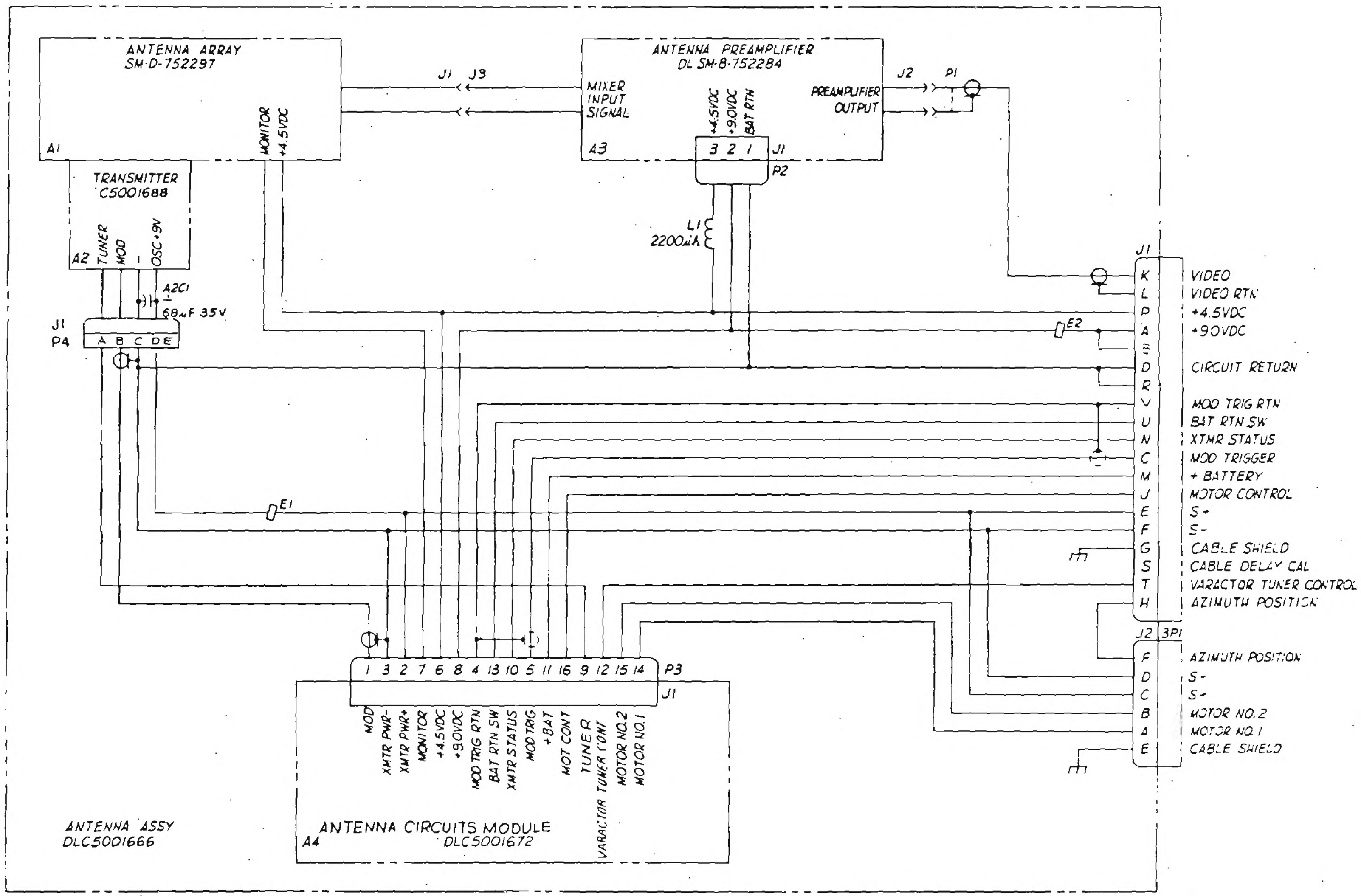
NOTES:

1. PARTIAL REFERENCE DESIGNATIONS ARE SHOWN. FOR COMPLETE DESIGNATION PREFIX WITH 3.

2. UNLESS OTHERWISE SPECIFIED:
   ALL RESISTANCE VALUES ARE IN OHMS.
   ALL CAPACITORS ARE IN μF.
   ALL DIODES ARE SM-B-752269.
   ALL VOLTAGES ARE DC.

Antenna Drive Unit 3, Schematic Diagram

Figure D-4. Schematic Diagram of the Antenna Drive Unit.



Antenna Assembly Unit 2,
Interconnection Diagram
(Model B)

Figure D-5. Antenna Assembly Unit Interconnection Diagram.

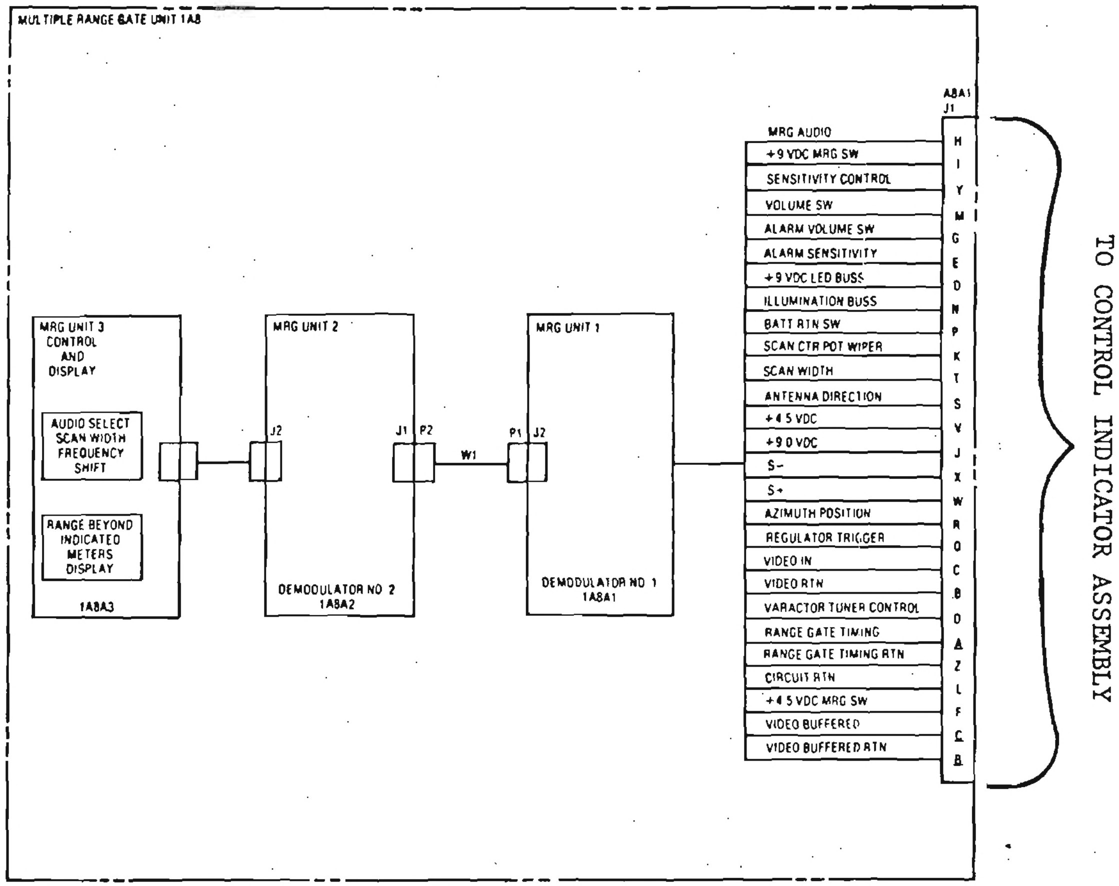


Figure D-6. MRG Unit Connection Diagram.

connector J1 as shown in the Antenna Assembly Interconnection Diagram in Figure D-5. The same signals also are available at pins X, W, and R on the connector to the MRG unit as shown in the schematic in Figure D-6.

The positional information from the pedestal potentiometer exists in digital form on the digital readout panel of the radar. This is the desired form needed by the signal conditioning unit in the Netting Preprocessor/I-O Interface unit. However, the difficulties encountered in trying to connect to this digital signal may be greater than simply converting the analog voltage through a simple analog-to-digital converter contained in the Netting Preprocessor.

Since both of the proposed system modifications are based on a track-while-scan radar surveillance principle, the above discussions of interface requirements, sector scan widths, etc., apply equally to both configurations. The provisions in the communication word formats for remote control of such functions as pointing direction are not addressed in this system option, but exist as a possible future design option.

Signal Processor Interface Requirement. The driving design consideration in the first modification option is to make maximum use of the seven range bin signal processor contained in the model B radar set. A functional block diagram of the Multiple Range Gate Processor is given in Figures D-7 and D-8. CMOS switches in the MRG unit perform the range gating process of switching the amplified radar video into a separate storage capacitor for each range gate in sequence. Each of these storage capacitors, in conjunction with the gated source, forms a simple low-pass Doppler filter for each range bin channel. In a similar manner, an additional capacitor per channel and the common gated resistor are used to provide high-pass filtering. Each range-gated Doppler signal is applied in sequence to one input of each of two wideband analog multipliers. The second multiplier inputs are always all-range high-speed and low-speed target Doppler signals. Since these reference all-range Doppler signals have a relatively high signal-to-noise ratio, the multipliers synchronously detect the relatively noisy range-gated Doppler signals using the all-range Doppler signal as a coherent reference. The multiplier outputs are sequentially switched to an individual low-pass filter for each range gate that integrates the synchronously detected Doppler for a period corresponding to the duration of the look on each radar scan. These filter outputs are applied to a threshold comparator whose threshold is controlled by the sensitivity (SENS) control to set the probability of false alarm to the required level.

This point (indicated on the block diagram in Figure D-8) is an ideal point to interface with the MRG unit through a set of buffer amplifiers. Performing this

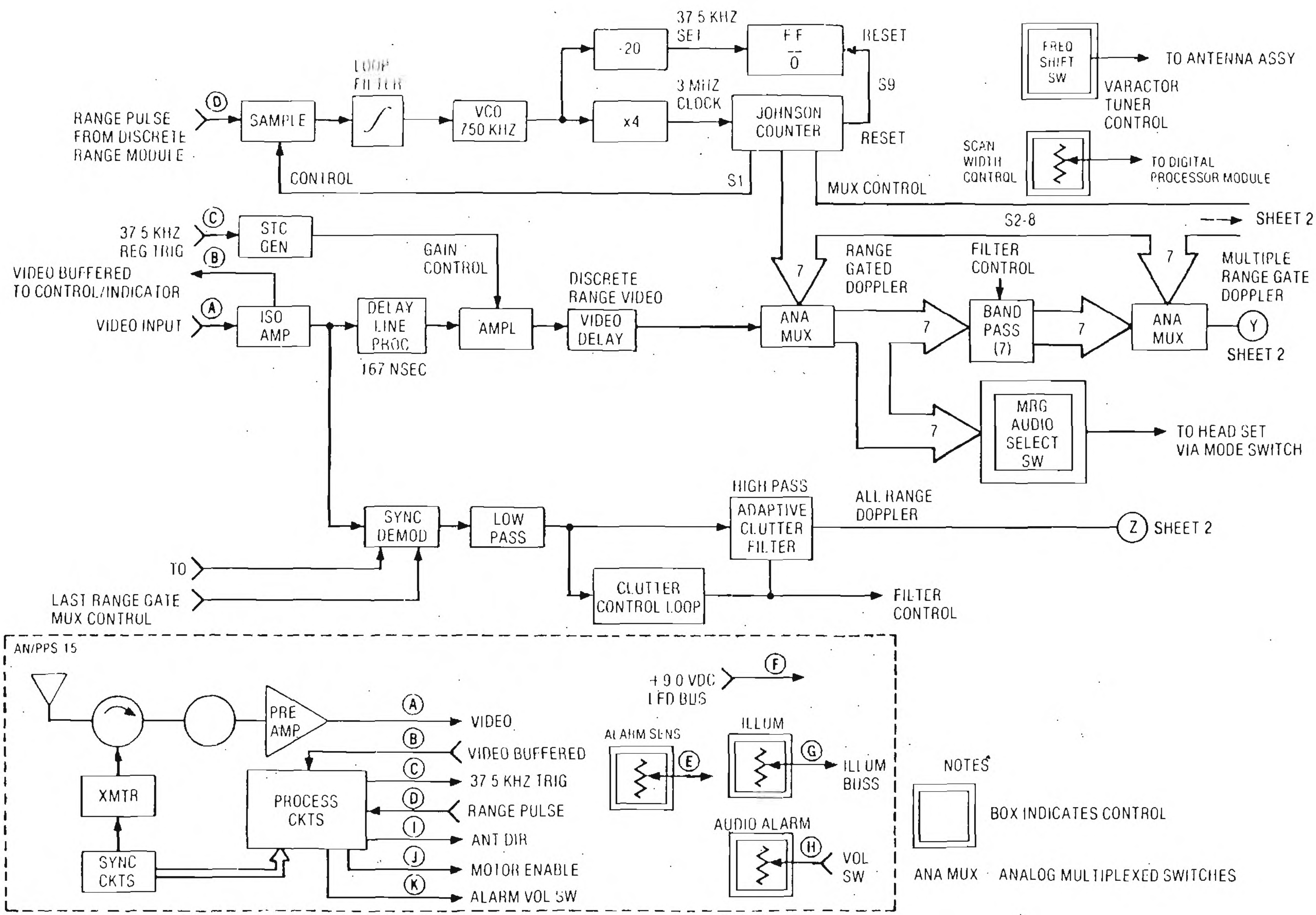


Figure D-7. Multiple Range Gate Processing, Functional Block Diagram (Sheet 1 of 2)

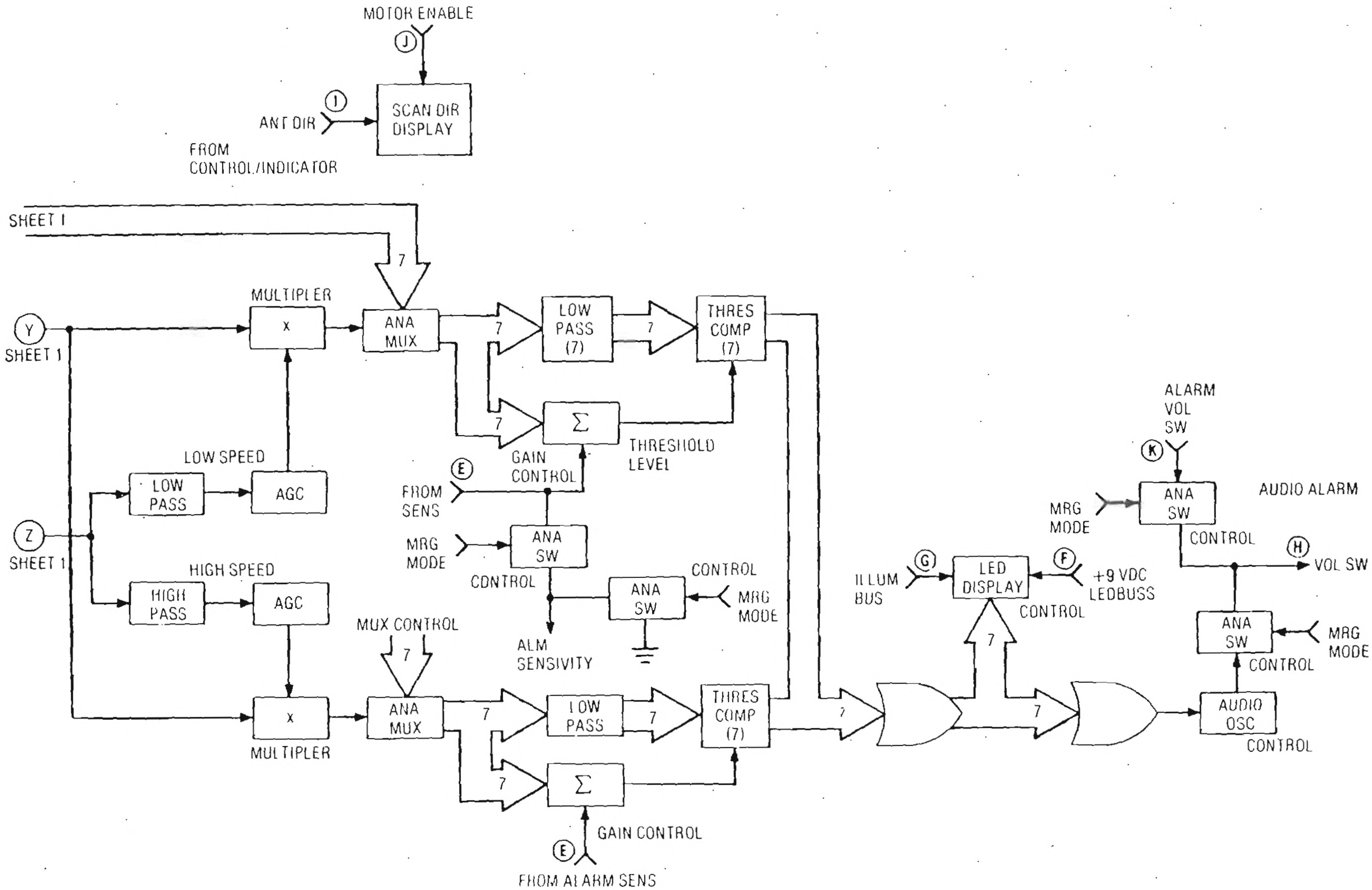
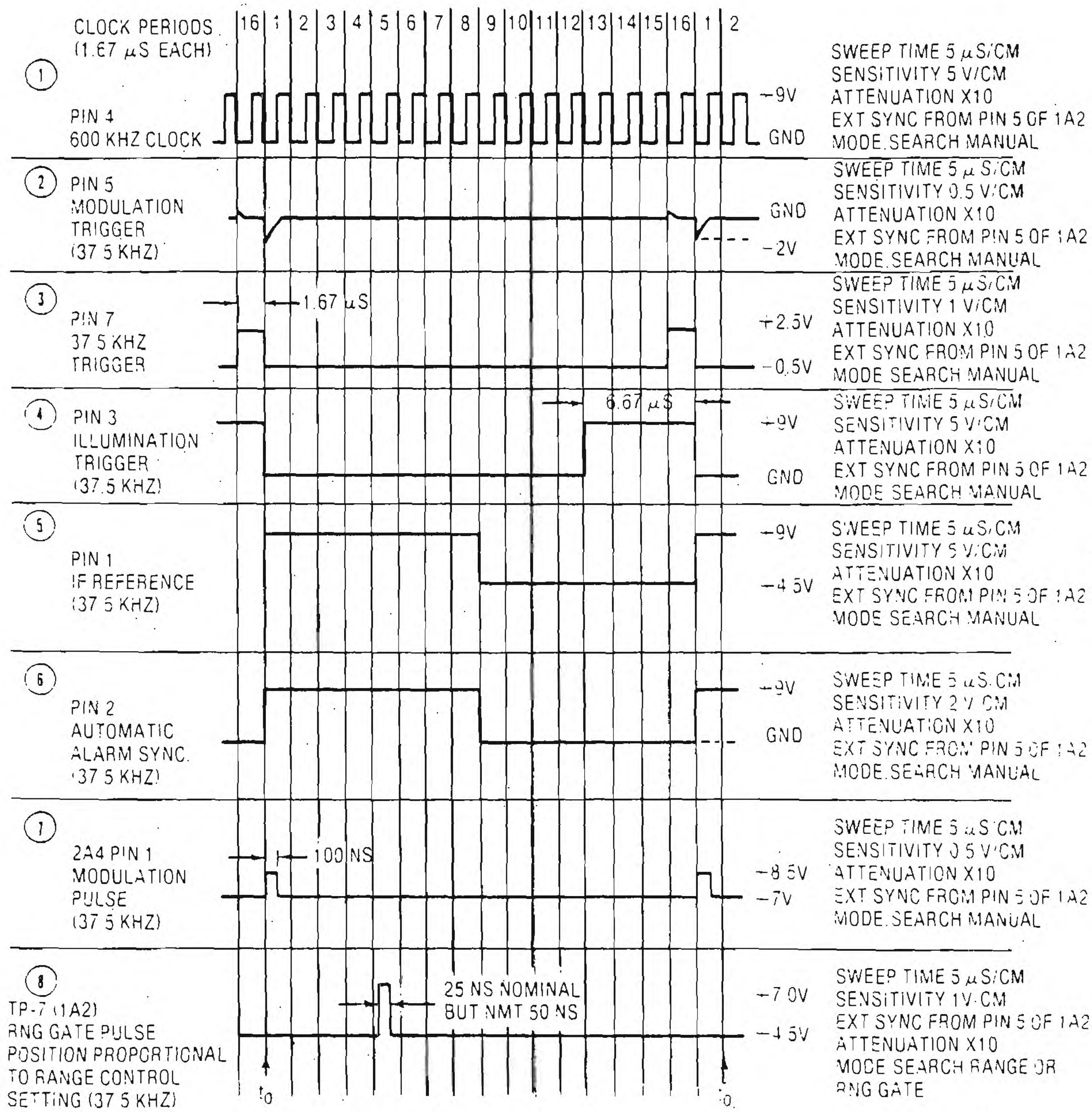


Figure D-8. Multiple Range Gate Processing, Functional Block Diagram (Sheet 2 of 2) interface before thresholding in the radar set makes the output to the Netting Preprocessor/I-O Interface insensitive to adjustments in the manual SENS control. The filtered range-gated signals will then be converted to a digital form in the Signal Conditioning section of the Netting Preprocessor. Each range bin channel is monitored by the microprocessor to determine the average "target" activity. This information can then be used to automatically set the reference threshold level to maintain a prescribed false alarm rate. This Constant False Alarm Rate (CFAR) algorithm can be accommodated entirely within the software of the microprocessor and is a very desirable feature for the nettable radar sensor.

One additional requirement must be met in order to operate the modified AN/PPS-15(B) in a netted configuration. The radial distance to the center of the occupied range bin must be determined to specify the position of detected targets. This condition may be easily fulfilled if the distance to the range bin can be determined in the Netting Preprocessor/ I-O Interface unit. The MRG unit provides seven range bins (each with a nominal 50 meter resolution) that may be positioned to provide a 350 meter surveillance zone where intruding targets can be detected and tracked via computer hardware/software algorithms. The range to the center or edge of this surveillance zone can be changed by means of a mechanical adjustment on the radar set control panel. The distance to the intruding target can easily be computed by entering the manually adjusted distance to the first range bin into the microprocessor. Alternately, the distance to the first range bin may be determined from the timing pulses contained in the radar set. An alternate method of operating the MRG exists, in which the seven range bins are positioned with large blank areas between each range bin. While this is very useful to a dedicated radar operator monitoring a scenario of troups or infiltrators moving across a battlefield, the large spacing between the range bins in this operating mode precludes any automatic tracking of invidual targets.

The range bins are located to the nearest range gate position corresponding to the basic AN/PPS-15 range gate. Subsequent gate or bin positions follow at contiguous 50 meter increments. All timing in the radar signal processor is referenced to a crystal controlled oscillator within the radar set. This unit sets the PRF of the radar to correspond to a range of 4000 meters per cycle and the range gate clock to 50 meters per cycle. A typical timing diagram is given in Figure D-9. Synchronization with the radar set is desirable in meeting two requirements. The distance to the first range bin can be automatically computed by measuring the time difference between the modulation pulse (waveform 7 in Figure D-9) and the range gate pulse (waveform 8 in Figure D-9). This



NOTES 1. PIN NUMBERS ARE DISCRETE RANGE ASSY 1A2 CONNECTOR PINS EXCEPT AS NOTED.
2. CIRCLED NUMBERS ARE WAVEFORM NUMBERS SHOWN IN FIGURE 1-9 AND 1-12.

Figure D-9. Timing Waveforms

measurement can be accomplished to the resolution of a range bin by simply counting the 600 kilohertz clock periods shown in waveform 1 of Figure D-9.

Timing information is also required to flag the detection time on the target report from the Netting Preprocessor/I-O Interface. This may be accomplished by further division of the timing reference obtained from the radar set or from an independent real-time clock contained in the microprocessor assembly of the Netting Preprocessor Unit. A resolution in this time reference of at least one second is recommended in Appendix B. Provision must be made to routinely synchronize this clock with the central netting computer. This can be accomplished from the time reference contained in the command words used for initialization and routine status checking.

Radar Sensor Status Reporting. One basic requirement placed on the remote operation of the radar set as a sensor for a netted surveillance system is the built in status check and tamper report. Provisions for three messages are included in the communication words defined in Appendix B. Several operational checks can be programmed into the radar set to give a measure of confidence in its surveillance capability. The Command Word routinely initiates the self test function by a two-bit message contained within the word format. The Data Word contains one of four possible responses to the self test initiate command. These responses acknowledge the request, signify that the system is "OK," and indicate equipment failure or degraded performance. To accommodate this function, the radar should also be instrumented to allow the Netting Preprocessor/I-O Interface to monitor the battery voltage within the radar set (if the system is not operated from a central power system) and the transmitter power monitor. This information should be sufficient to determine that the transmitter portion of the system is functioning. The operation of the receiver (and a general measure of the overall system performance will be indicated in the detection activity count being made within the microprocessor software in support of the CFAR algorithm. Correct receiver performance will be indicated by a nominal level of threshold crossings assuming that the transmitter/antenna system is functioning properly. The detection rate considered here will be higher than the false alarm rate experienced at the output of the central netting computer due to the filtering action of the target detection and tracking algorithms. The details of these algorithms are presented elsewhere in this report. The information on battery voltage, transmitter power output, and detection activity should be sufficient to define the status message responses outlined in Appendix B. This function should be accomplished in the software of the Netting Preprocessor/I-O Interface unit.

The tamper report of the Data Word is used to indicate deliberate interference with the remotely operated radar set. As a minimum requirement, equipment entry switches and a movement sensor should be included within the set for this function. **The equipment entry switches should include cover doors over the operating controls of the radar to prevent undetected changes in the settings.** A tilt or movement sensor should be installed to detect a possible change in the pointing direction if the unit is to be operated on a small portable tripod. Additional tampering detection algorithms can be installed to monitor electromagnetic countermeasures (jamming) and the aproach of personnel (proximity detectors) if so desired. The proposed Data Word as defined in Appendix B accommodates these tamper report catagories.

Future Expansion Capabilities. Several functions have been included within the netting interface description presented in Appendix B that are not addressed in this modification option. Such options as remote monitoring of the Doppler audio by the system operator is desirable, but is not considered necessary as a minimal operating capability for remote netted operation of the radar. Other desirable features that are not considered essential are further remote controls on the radar set. These options have been provided for in the communication word formats and can be included in future system designs as required.

D.2.3.2 Fully Implemented/Track While Scan Option

The second proposed modification for the AN/PPS-15(B) radar set is an alternate signal processor that can simultaneously monitor target activity in contiguous range bins over the usable portion of the radar beam. This coverage will account for approximately 30 of the the 50-meter resolution range bins similar to those used in the current radar design. The difference in the first and second proposed modification options is in the development and interfacing of the 30-range-bin signal processor. The data-link interface to the central netting computer will be identical to that defined in Appendix B and discussed above.

A block diagram of the proposed fully implemented track-while-scan modification to the AN/PPS-15(B) radar set is shown in Figure D-10. One additional function (the Signal Processor Unit) has been introduced into this system to handle the increased signal processing load. All of the basic interconnections to the radar set are identical with those previously proposed with the exception of the receiver video or MRG output. In this modification option, the required interface may be performed before the sampling or gating process if the MTI signal processing is done in the Signal Processor Unit.

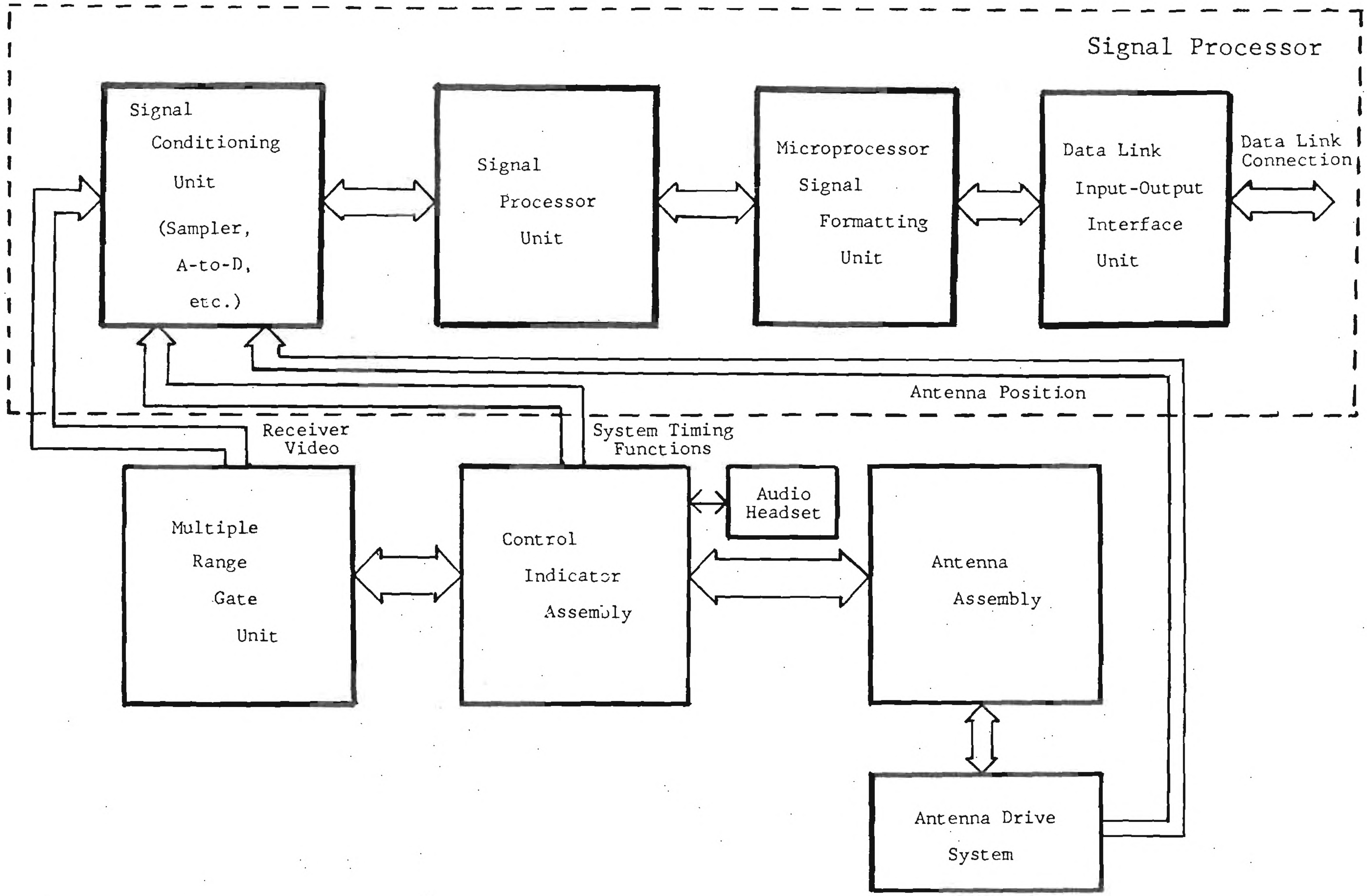


Figure D-10. Block diagram of proposed fully implemented netting interface (all thirty range bins) for AN/PPS-15(B) radar.

Alternately, the interfacing may be performed at the output of the MRG unit if this hardwired processor is expanded to include the required number of range bins. These interface requirements will be developed further in the following discussions.

The proposed Data Word format is capable of supporting the expected target load from the expanded surveillance area of each radar. The Data Word defined in Appendix B for the short range sector scan radar allows only one ORC report per data word, and the 1200 baud rate established by the SEIWIG-005 requirements gives a maximum communication rate of 15.6 words per second. While some Data Words may be responses to a status check request from the central netting computer, this rate establishes the maximum target reporting rate at approximately 15 reports per radar per second. The 5 degree per second scan speed and the 5.6 degree beamwidth of the AN/PPS-15(B) radar will allow target or ORC reports to be made from at least one-half of the proposed 30 range bins during one pass or look of the radar antenna. Target activity of this level would typically be considered a near overload condition for this clutter referenced coherent radar system. This means that the proposed netting algorithms and data link system should be more than adequate for processing the maximum expected load of this fully instrumented radar set.

The same operating scenario for the radar sensors will be used in the fully implemented track-while-scan modification. The pedestal interface requirements for this modification option are identical to the first option, and the discussions above applies here also. This includes the requirement for reporting the absolute pointing angle of the antenna to determine the azimuth position of the occupied range cells with the resolution defined in Appendix B.

The noticable effect of this modification to the radar will be an increase of approximately four in the surveillance region available at any instant from each radar set. This results in a capability for following intruding target tracks for longer distances on the scenario-map operator display. When a single radar system is used, the proposed detection/tracking algorithms must have a preset number of associated detections to initiate a track. This extended coverage of the full range signal processor will improve the performance and usefulness of these algorithms. Overlapping coverage of two or more radar sets will also increase the coverage for systems using both the fully or partially implemented signal processor.

Fully Implemented Option - Version I. The expansion of the signal processor to instrument the full detection range of the radar set is a very desirable capability and at least two versions may be considered. One obvious approach is to duplicate sections of the Multiple Range Gate processing unit to gain the required additional channels of processing. Since the MRG processor design may currently be adjusted to position the seven contiguous range bins at essentially any point between the minimum detection range and the maximum operating range of the radar, this approach offers a low risk processor expansion to the full range capability at only a slight increase in system complexity, size, cost, and power consumption. The parallel functions of four MRG units can provide 28 range bins, essentially instrumenting all of the usable detection range of the radar. The first MRG unit would be triggered by the range pulse from the discrete range module. The range to the first sampling gate should be locked at its minimum value. An additional circuit modification would also be required to trigger each successive MRG unit so that the first range gate in the second, third, and forth MRG units follow contiguously upon the last range gate of the previous unit. This concept is illustrated in the block diagram in Figure D-11.

The interface between the Signal Conditioner Unit and the four MRG units must have a multiplexer capacity sufficient to handle the 28 range bin channels. The analog-to-digital converter must be able to convert these samples at a real time rate equal to the product of the number of range bins and the PRF of the radar. Twenty eight range bins and a 3 kilohertz PRF require a conversion rate of 84,000 per second. Current technology in analog-to-digitial converters is capable of megasample conversion rates with an eight-bit resolution. Higher resolution (10 to 12 bits) can be obtained at slightly lower conversion rates). Therefore, the interface with the four MRG units is not considered to be a technical limitation to this system modification.

In this version, performing the primary signal processing in the four MRG units, the Signal Processor Unit will be used to perform the dynamic CFAR thresholding functions for each range bin. This algorithm is discussed in the previous radar modification description and must be performed on a real time basis for each of the 28 range bins. The Microprocessor-Signal Formatting Unit acts as the buffer and communication message center to the data-link and the central netting computer. The computation of the location of occupied range cells is also performed in this unit. All of the modifications described in this version of the fully instrumented radar signal procesor appear to be well within the state-of-the-art of the required hardware and software.

Fully Implemented Option - Version II. The second approach to providing the full range signal processor capability is to completely replace the signal processor in the AN/PPS-15(B) radar. The initial task for this approach would be a study of the current signal processing chain or hierachy to prevent an unnecessary reinvention of the wheel.

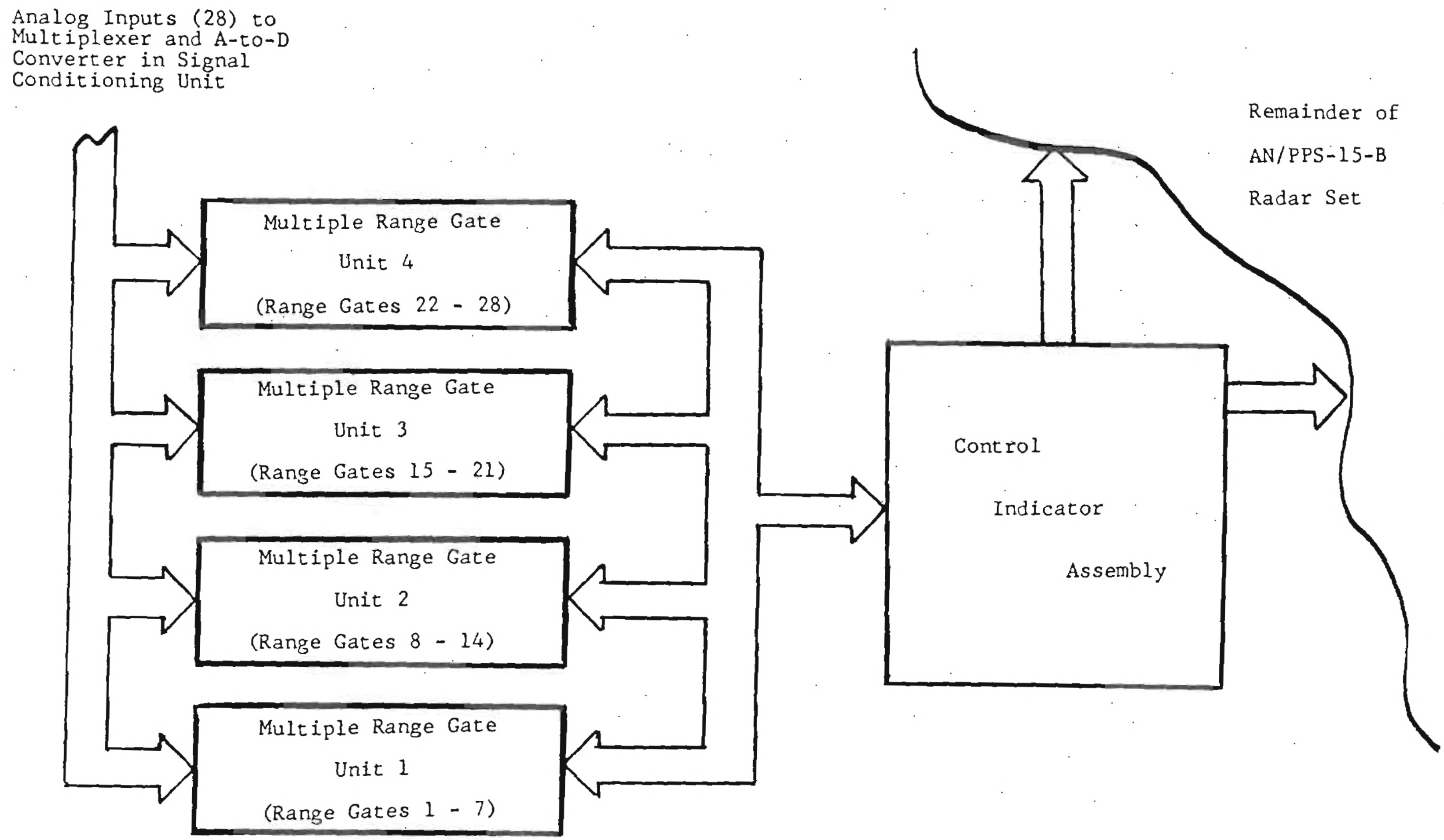


Figure D-11. Block diagram of four multiple range gate unit modifications for a fully instrumented processor.

Table D-3 lists the basic signal processing steps as they appear in the radar signal processing chain. Some of the functions in the current model B design are not applicable to the all-range modifications (such as the range-gate hold-off waveform that is used to blank range bins not being processed). Other functions not included in this list are recognized as being very desirable for the all-range radar processor for netting applicatons (such as the CFAR algorithm).

The sensitivity time control (STC) gain controlled amplifier is used to reduce the radar receiver sensitivity inversely as a function of range to reduce problems of receiver saturation for close-in targets. This process is a necessary function that is considered most suitable to be performed in the analog circuitry of the present radar signal processor. This means that the "radar video" interface to the radar set should be made following this circuit, but the function of the range-gate hold-off waveform applied to the gain controlled amplifier must be eliminated or inhibited. Figure D-12 shows the first portion of the Multiple Range Gate Unit in block diagram form. The proposed interconnection to the radar video is shown here at the input of the analog multiplexer. This interface should include the restrictions that (1) suitable buffering of the signal is provided and (2) the effects of the range-gate hold-off waveform have been eliminated from the video signal.

The function of the range gate sampling of the radar video is replaced by converting to a digital value the samples of this analog taken at intervals corresponding to the two-way propagation time from the center of each range bin. The multiplexing and demultiplexing of these digital samples will be accomplished in the hardware/software of the Signal Processor Unit. The normal sequence of processing operations in the MRG unit (see Figure D-12 and D-13) is to synchronously demodulate the Multiple Range Gate Doppler (signal Y of Figure D-13) with the All-Range Doppler (signal Z of Figure D-13) by means of the two analog multiplier circuits. This process simply makes use of the strong radar return from the ground clutter as the coherent reference for this <u>moving target</u> signal processor. The multiplying operation can easily be performed in the proposed digital system, but the conversion of the All-Range Doppler signals must be made in proper time sequence to correspond to each range bin sample. This must be done for both the high pass filtered signal (high-speed) and the low pass filtered signal (low-speed). The suggested interface to these two signals is illustrated in Figure D-13 at the respective outputs of the two AGC (automatic gain control) circuits.

The functional block diagram in Figure D-13 shows the output of the two analog multipliers being sorted in the analog multiplexer to the seven individual low pass

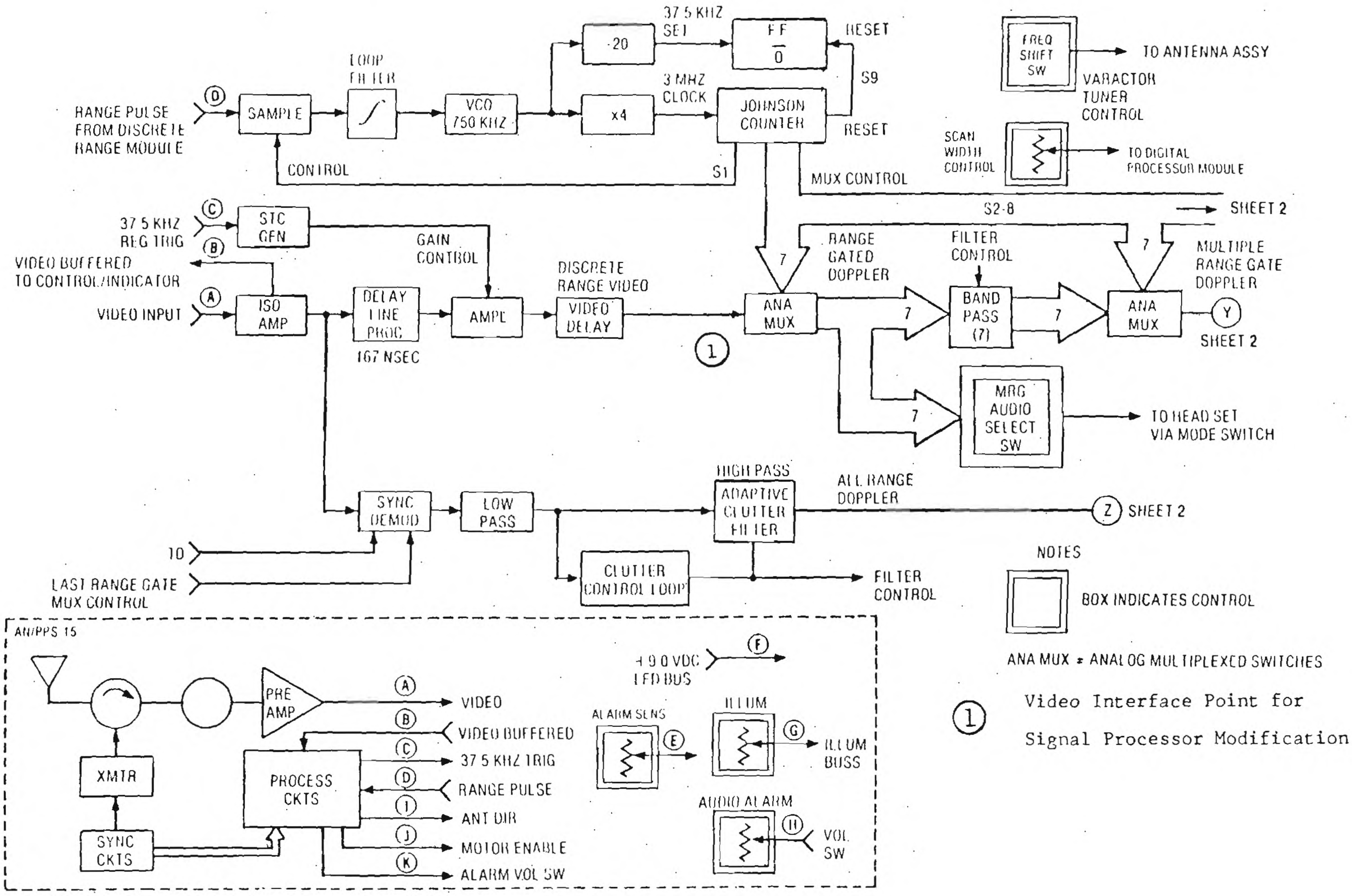


Figure D-12. Multiple range gate processing block diagram (Part 1) showing proposed interconnection to radar video.

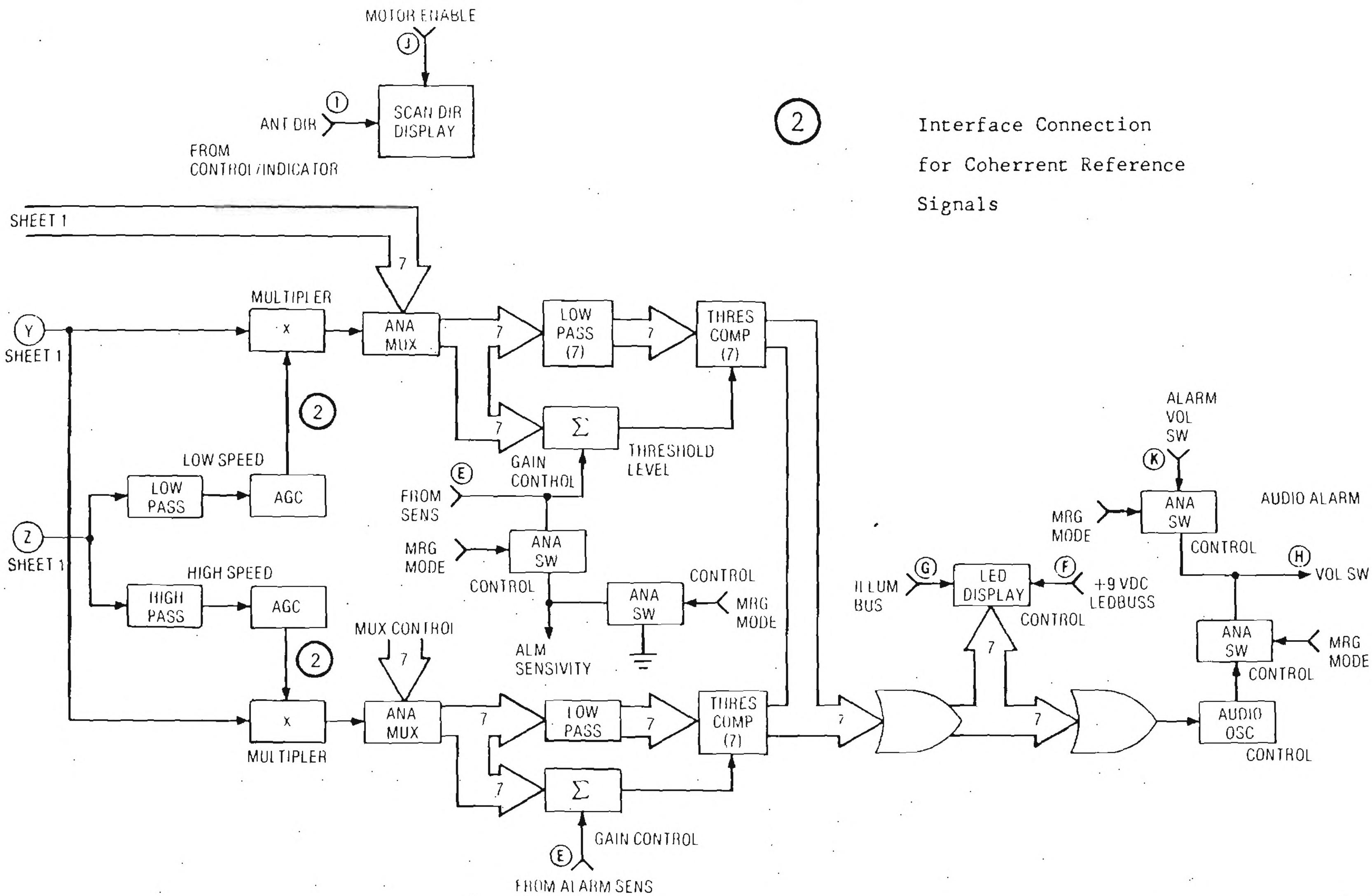


Figure D-13. Multiple range gate processing block diagram (Part 2) showing proposed interconnection to all range reference signal.

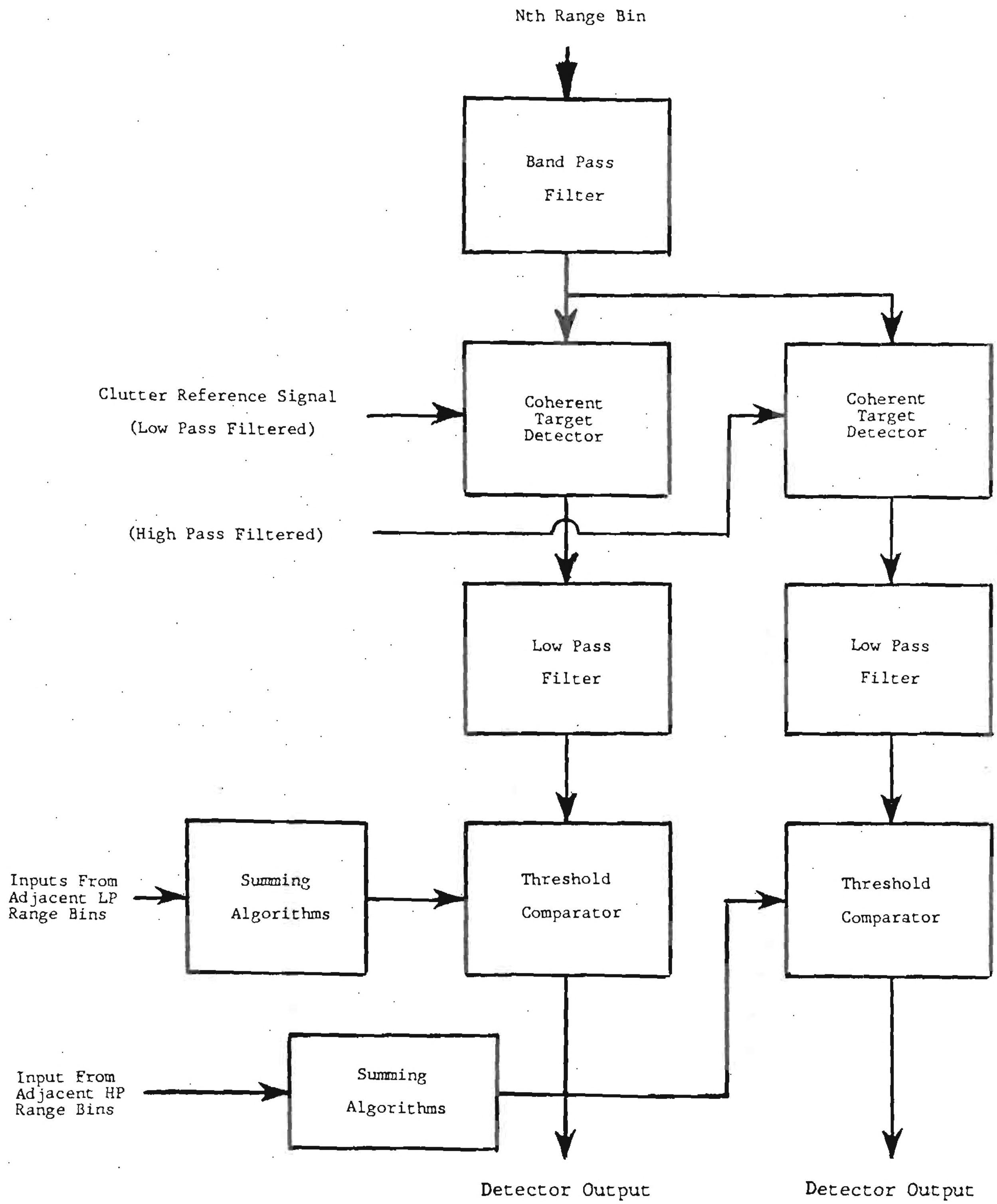


Figure D-14. Flow chart of CFAR signal processing concept.

filters. The time constant or averaging integration time of these filters is approximately equal to the time for the radar beam to scan over a target. Target activity in each range bin is monitored by threshold detecting the output of each range bin with a threshold controlled by the manual setting from the radar control panel and the target and clutter activity in the adjacent range bins. This provides a "detector" with a threshold setting that decreases the sensitivity of the system when the number of responses from wind-blown clutter, etc., increased the false alarm rate above a desired level. This is the basic range - only CFAR algorithm discussed in a previous section. These basic functions can be accomplished in the software of the Signal Processor Unit.

The CFAR algorithm is an adjustable threshold detector for moving target activity in each of the range bins. This function can be implemented digitally as outlined above in the hardware and software of the Signal Processor Unit. A simplified flow chart of this processing concept is shown in Figure D-14. This processing is applied to each range bin in real time. The digital signal processing functions and their sequence in this flow chart parallels the operation of the AN/PPS-15(B) radar processor shown in Figure D-12 and D13.

The CFAR threshold must be computed from the radar return activity detected in the adjacent range bins. In a digital system, it is practical to make this computation on a dynamic basis for each range bin. Experience has shown that somewhere between 4 and 10 independent range-bin samples can provide an effective sample of the alarm rate to be expected in the candidate range cell being considered. Figure D-15 indicates the concept of monitoring the activity in the 3 range bins immediately above and below the candidate range bin. This process must be performed for the output of both coherent target detectors. The averaging of six adjacent range bins approximates the summing function used in the current MRG signal processor. A modification of this averaging algorithm must be made for operating at the first three and at the last three range bins. When the candidate range bin being calculated is in position 1, 2, or 3, a total of 3 range bins does not exist to the left (see Figure D-16). One solution is to pick up the lost range bin on the other side of the candidate range bin in order to keep a total of six bins as inputs to the CFAR threshold estimate. This concept is shown in Figure D-16). A complementary argument is used for operation of this CFAR threshold averaging algorithm at the far range cells.

Alternate Modifications. This version of the fully implemented/track-while-scan radar system is basically a parallel implementation of the moving target detection algorithms used in the current AN/PPS-15(B) radar design. Alternate modification

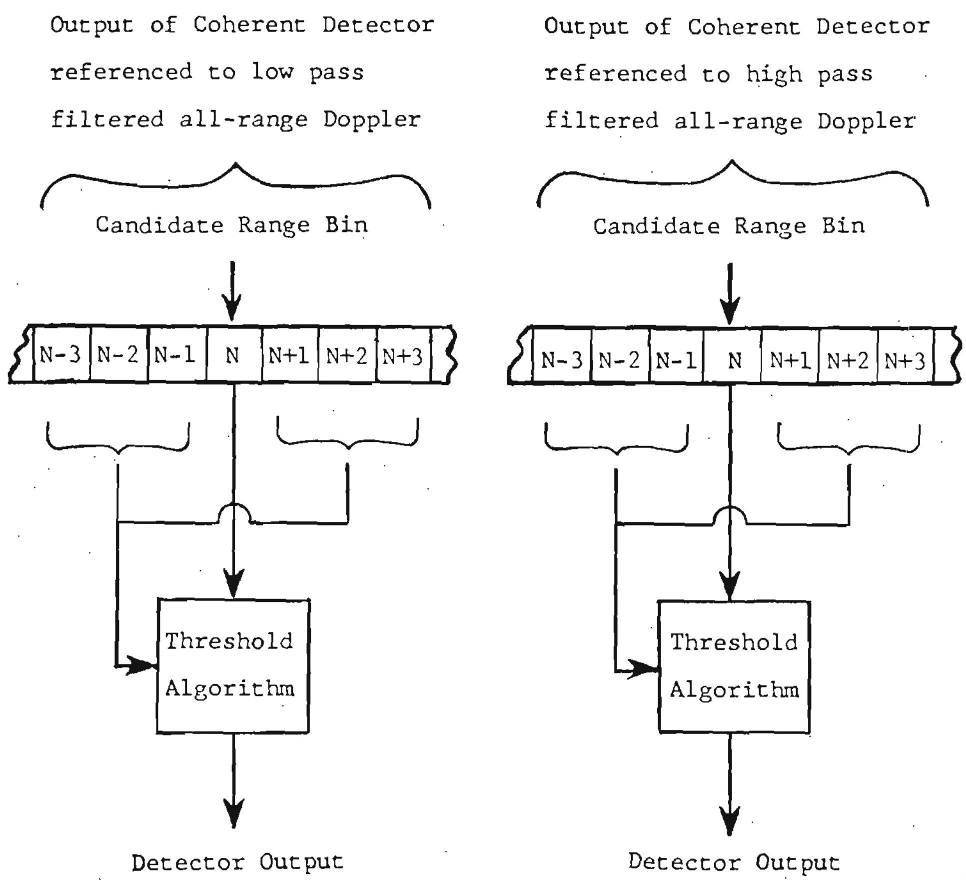
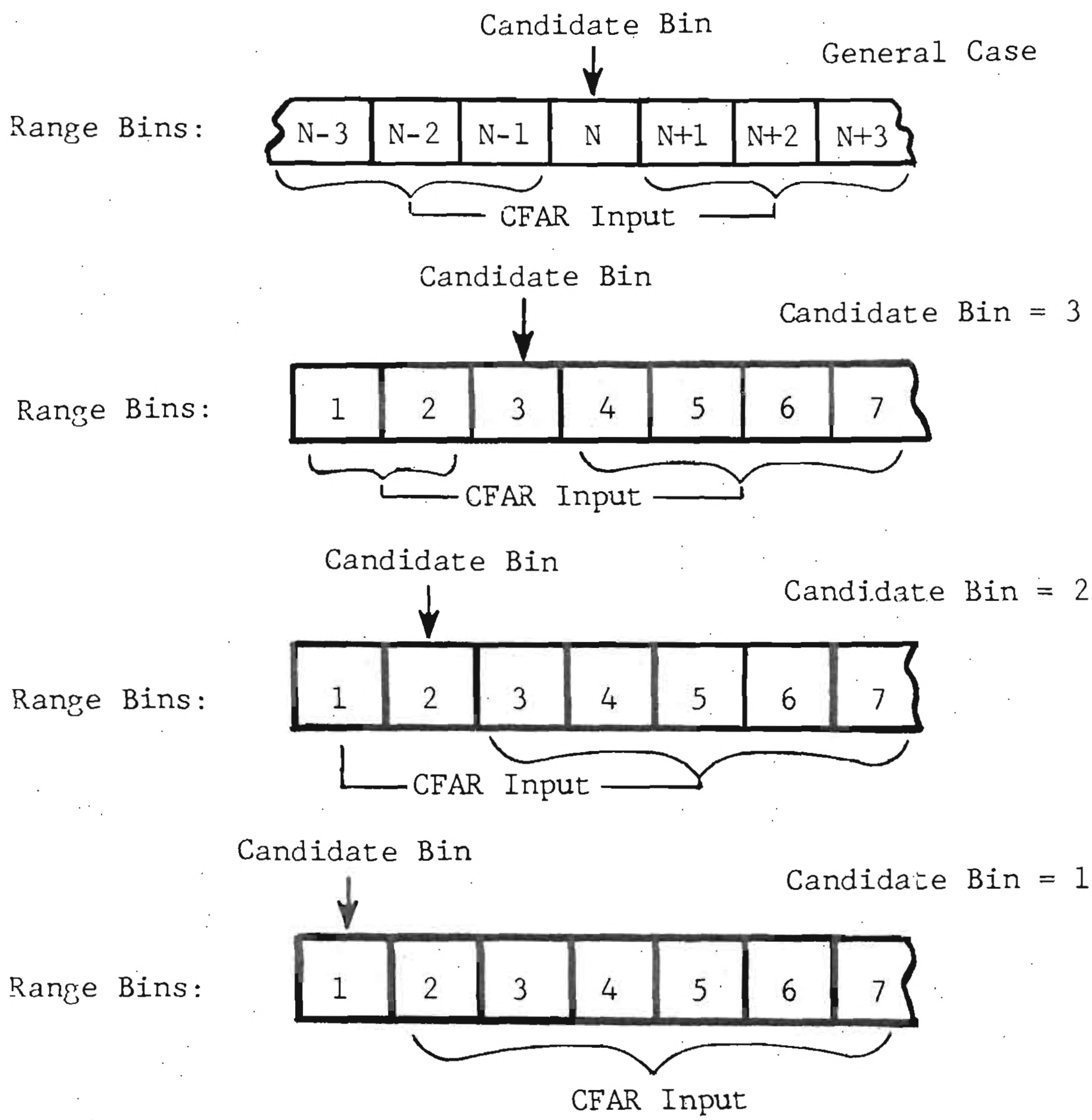


Figure D-15. General flow chart of the concept of CFAR averaging algorithm.



Note: A complementary case exists for the far end of the range cells (bins 28, 29, and 30).

Figure D-16. CFAR algorithm for end of range calibration.

schemes for this radar are possible that affect the radar as well as the signal processor. More flexibility in the approach would be possible if the radar were a truly coherent radar design. This would significantly alter the signal processing approach used and the software and hardware techniques used to implement the moving target processor.

Modern integrated circuitry can provide MTI processing and analysis using discrete or fast fourier transforms. This analysis approach will not only provide an alternate method of separating the moving targets from the stationary and slow moving ground clutter, but will allow target radial velocity to be determined. If the frequency domain processing has sufficient resolution, two targets having different radial velocities may be separated when in the same resolution cell. Advanced analysis algorithms may also use the high resolution FFT outputs for classification of the target or target type.

One additional concept that may be desirable in future modifications of the signal processor is the inclusion of an azimuth bin splitting algorithm. This would use predictor algorithms to estimate the location of a target in azimuth position with a pointing resolution that is better than the radar beamwidth. The accurate operation of this algorithm depends upon only one target being within a given range-azimuth cell; otherwise it predicts the centroid of the multiple targets.

Mechanical Configuration. The circuit modifications proposed in this section may easily be configured in a box that may be located adjacent to the existing MRG/Remote Control Indicator and connected to the AN/PPS-15(B) radar by electrical cables. This concept is pictured in Figure D-17 where the additional circuit box is placed on the ground when the radar unit is operated on the portable tripod. The tamper-proof modifications would require that the radar unit be modified to prevent undetected movement or adjustment of the operating controls.

D.3 SUMMARY

The basic concept for adapting the AN/PPS-15(B) radar to operate effectively in a netted surveillance application with other radars and/or fixed location sensor systems has been presented. This approach has identified the minimum required information and the communication format proposed in Appendix B of this report that is required for netted operation of the radar sensor. Two alternate approaches were presented for accomplishing the required system modification to the existing radar design. Future expansion capabilities for the radar system are suggested. The approach used in identifying the netting interface requirements of this radar can find parallels in adapting other types of radar and sensor systems.

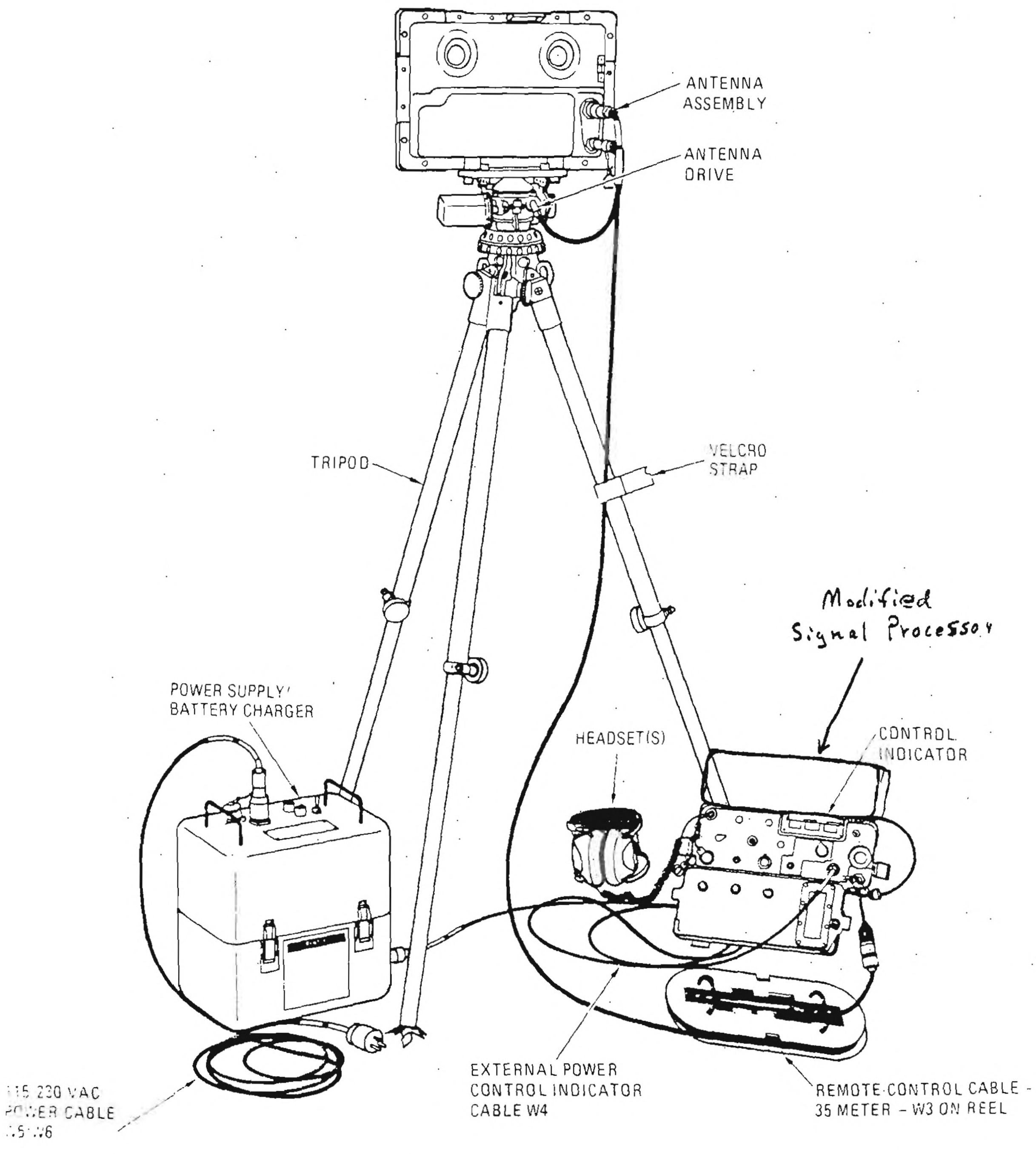


Figure D-17. Radar Set (Model B), Major Assemblies and Cables Related to End Item, Remote Operation.

The AN/PPS-15(B) radar with the signal processor modifications proposed above can meet the requirements for an effective netting radar sensor for the near-future surveillance requirements of the military. The proposed design changes represent a relatively low-risk and low-cost method for obtaining a radar security/surveillance capability.

APPENDIX E

COMPUTER HARDWARE CONSIDERATIONS

E.1 OVERVIEW

In this Appendix, some of the primary considerations for the hardware requirements of the data processors will be discussed. In particular, the specific functions of each major system component will be outlined along with the corresponding demands on the hardware.

As discussed in Section 2, a modular approach is desired for the system in order to provide for flexibility, expandability, and simplicity of development. (The building blocks of a modular system are less complex than a completely integrated system.) The basic block diagram of the system which was given in Figure 11 is reproduced here as Figure E-1. The system is composed of three major building blocks in addition to the sensors. These include the signal/target processor, the netting computer, and the display system. The required characteristics of each of these building blocks are discussed in this Appendix.

E.2 DESCRIPTION OF BUILDING BLOCK HARDWARE

E.2.1 SIGNAL/TARGET PROCESSOR

E.2.1.1 Functional Description

The complexity of the signal/target processor varies with the type of sensor. For a point sensor, very little signal processing is required since an alarm detection is usually a switch closure. All that needs to be done is to transform the sensor output into the proper format for transmission over the data link to the netting computer. However, for a radar sensor, the situation is quite different. Typically, the initial data rates for a radar sensor can be several Megahertz which is much higher than many digital computers can handle. The data rate seen by the signal processor depends on the number of radar resolution cells being covered by the radar and the percentage of signal processing functions which are performed by analog or digital hardware as opposed to being performed in the signal processor. The trade-off between performing these functions in hardware versus a computer involves trading high speed and low cost for hardware versus hardware simplicity and flexibility for the computer case. Typical functions which may need to be performed on radar data either in the radar circuits or the signal processor include: (1) integration to improve signal-to-noise or signal-to-clutter ratios; (2) constant false alarm rate (CFAR) processing to reduce clutter false alarms (sometimes

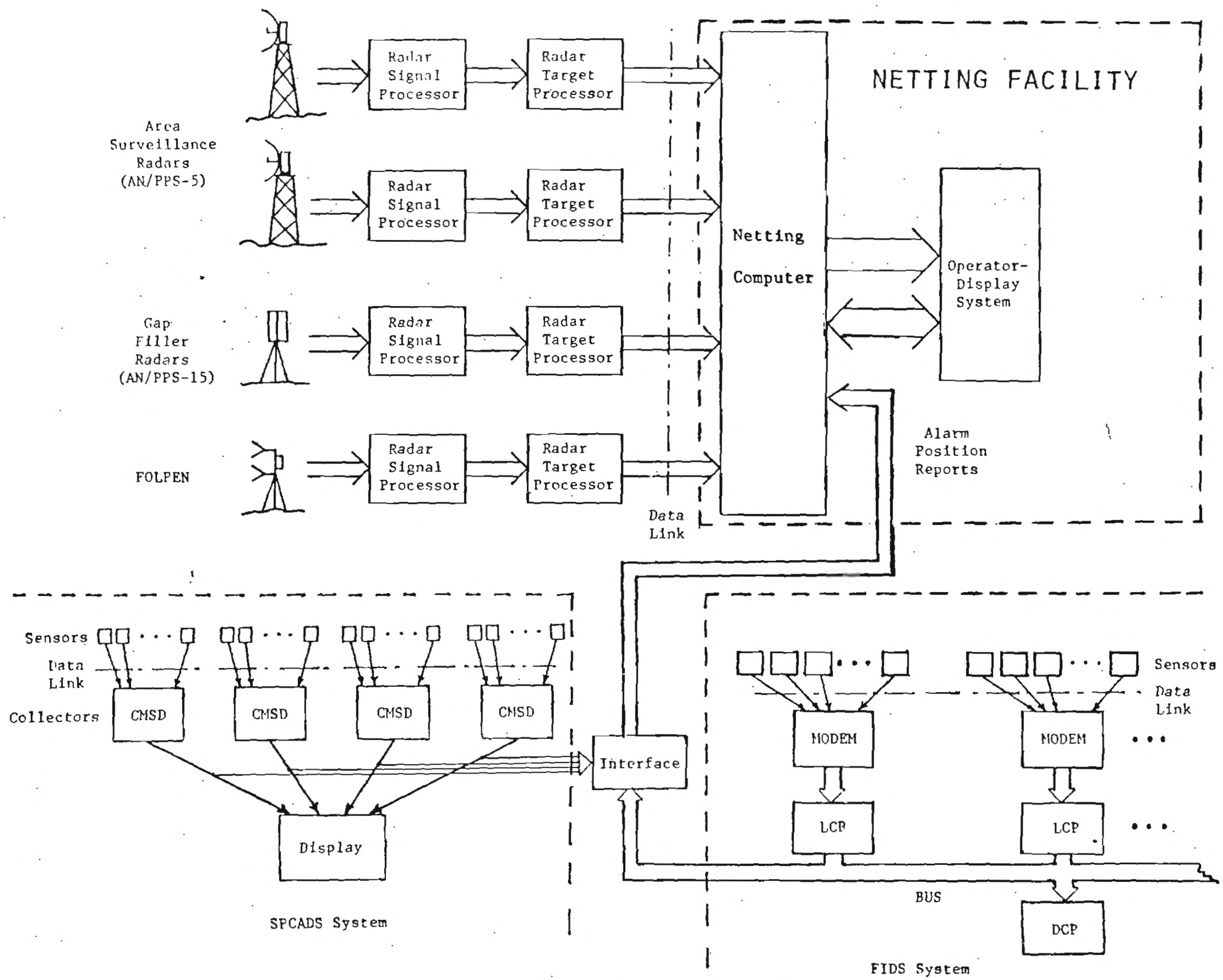


Figure E-1. General Configuration of a netted radar-fixed sensor system.

an adaptive CFAR, which adjusts the thresholds based on changing conditions, is needed to maintain desired false alarm rates); (3) moving target indication, to separate moving targets from fixed targets based on their relative Doppler frequency shifts (this function can be performed by a simple delay line canceler which yields position only or a Fourier transform which yields both position and radial velocity) (4) target masking, eliminating areas within the radar coverage area from processing, for example, a heavily traveled road or a high clutter area); and (5) target reports, generating a list of target reports based on a signal crossing a threshold from a given radar resolution area (such a report might include X coordinate, Y coordinate, velocity vector, and time of report). Figure E-2 gives a typical flow chart for the signal processor for the Target Detection Unit (TDU), automated radar sensor for detection of waterborne intruders.[4] For the case of the TDU, 32,000 radar resolution cells were contained in the active sector and the data had to be fully processed every 2.7 seconds. Thus, a very high speed, pipeline digital processor had to be used. However, for the AN/PPS-15(B) radar in the proposed configuration, the maximum number of resolution cells would be 7 range bins times 45 azimuth resolution cells for a 270 degree beamwidth, or only 315 resolution cells. The data rate for such a radar would be much lower than for the TDU. However, if a true track-while-scan implementation for the AN/PPS-15 were developed, then the number of resolution cells could approach 3600 for a 4000 m x 270 degree active sector (see Appendix D).

E.2.1.2 Hardware Requirements

The hardware requirements for the signal/target processor depend on the data rates and signal processing needs of the sensor. For a point sensor, a simple 8-bit microprocessor such as an Intel 8080 would suffice to perform the required reformatting process for the data words. For a radar such as the AN/PPS-5 (see Appendix A), a pipeline processor composed of the American Micro Device (AMD) 2900 series bit-sliced micrologic would be required to process the large amounts of data. Figure E-3 gives a block diagram of a "typical" pipeline processor which might be used for this application. Typically, the CFAR and MTI processes would be performed using special purpose digital hardware while the other functions are performed in the processor. For the case of the AN/PPS-15 radar which falls between the two extremes of a point sensor and the AN/PPS-5 radar, a 16-bit microcomputer such as the Motorola 68000 microprocessor would suffice. However, for simplicity one might want to specify only two levels of processing power, moderate and maximum capability. Thus, the 68000 and the AMD 2900 processors might be the two processors selected for the signal processor application.

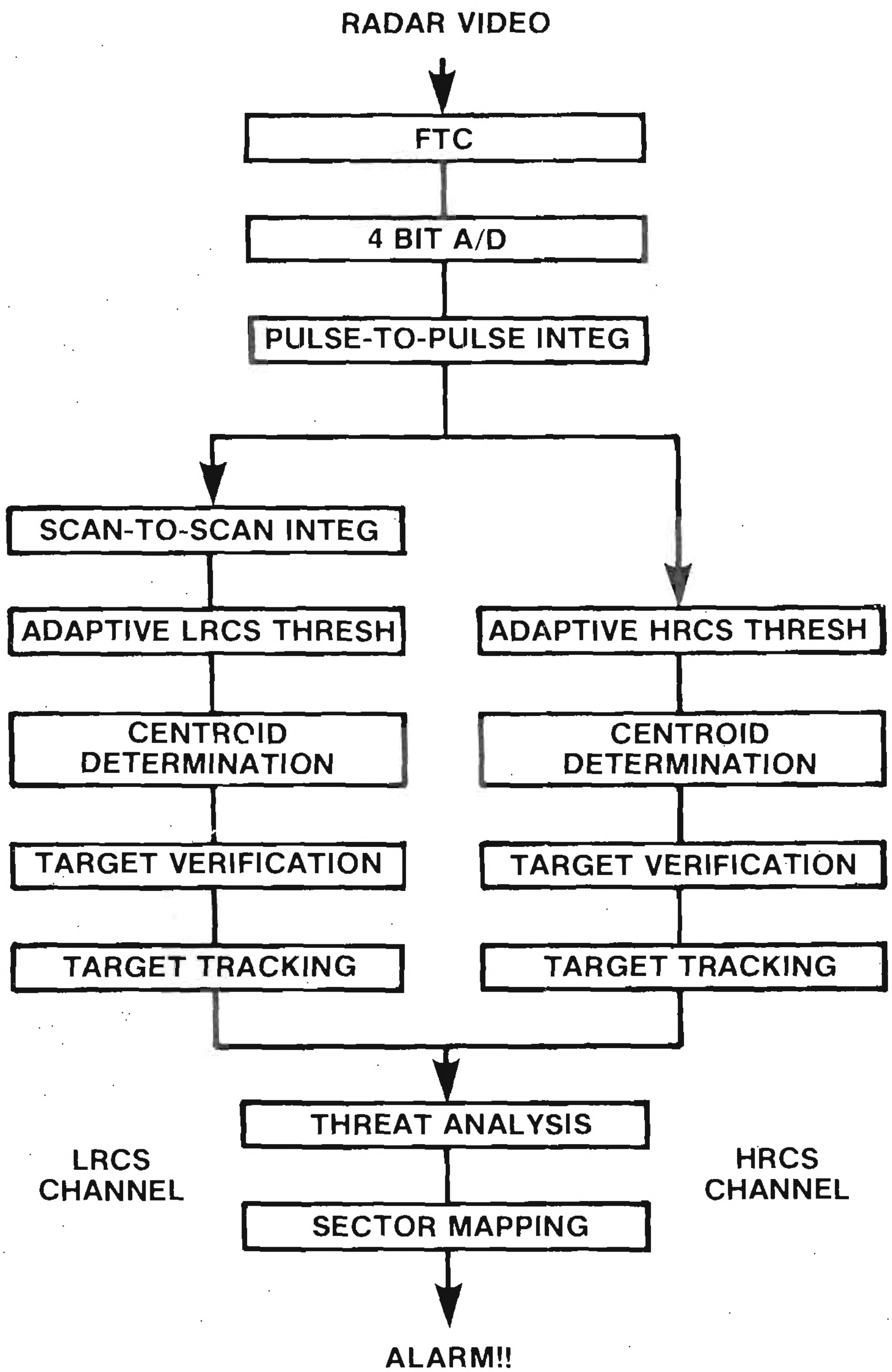


Figure E-2. Block Diagram Flow of the ADM TDU Processing

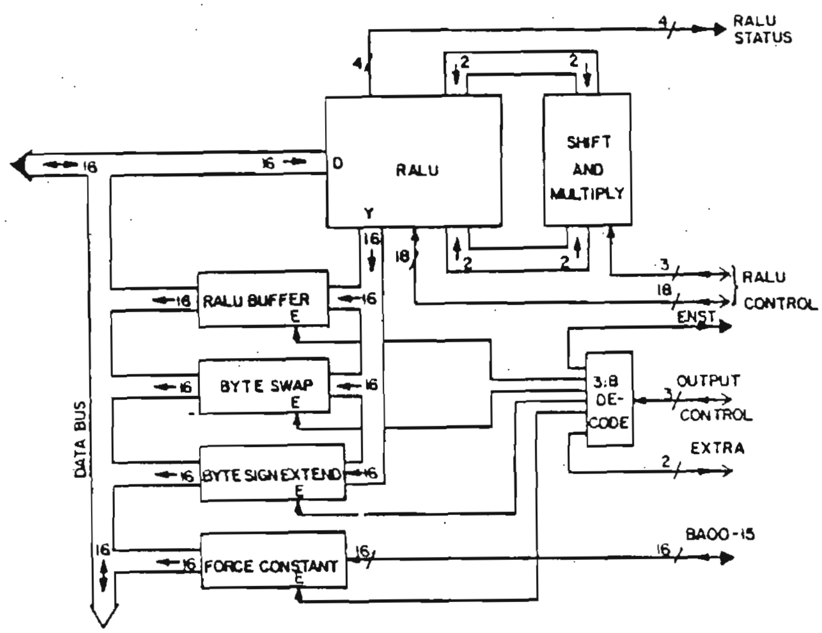


Figure E-3. Block Diagram of an AMD-2000 series pipeline microprocessor.

For the case of a radar signal processor, there must be an associated digital memory in which to store radar returns from each resolution cell for each scan. Thus, if the radar has 32000 resolution cells, then a 32 K RAM memory would be required in addition to program and variable memory (2-8 K of RAM memory). Normally, for the signal/target processor, program memory would be stored in PROM. In addition to the processing speed requirement, another speed consideration involves the time required to transfer data from the radar to the processor. Normally, the radar data are stored in high speed memory and then "read into" the processor through a direct memory access (DMA) function. Thus, the signal processor must have this capability.

E.2.2 NETTING COMPUTER

E.2.2.1 Functional Description

The netting computer as shown in Figure E-1 is the heart of the netted system and as such would contain the system mass data storage device such as a floppy or hard disk system. The netting computer would be expected to perform the following functions:

1. System Initialization - at system turn on, it would send initialization data such as a time reference, grid coordinates of each sensor, operational status, etc., to the various signal processors in the system It would also initialize the display by downloading map parameters from disc into the memory planes of the display.

2. Target Report Verification and Association - the alarm reports from the various sensors have to be decoded and compiled for display purposes. For the case of radar sensors, moving target reports must be associated into tracks, and multiple reports from two or more radars with overlapping coverage for the same target must be weeded out. In addition, it is highly desirable to correlate radar target tracks with fixed sensor reports to enhance the integrity of a given intruder report.

3. Sensor Message Decoding - one of the functions of the netting computer is to decode the sensor messages and to initiate proper responses to non-alarm reports such as failed self test or tamper.

4. Display Information - the netting computer performs the functions of the generation of messages and animated target information which is periodically transmitted to the display.

5. Operator Interaction - operator comments and responses which are generated on the display processor using either a keyboard or light pen may be transmitted to the netting computer for servicing. Generally, commands affecting the display only would be serviced in the display processor while system commands would be serviced by the netting computer.

E.2.2.2 Hardware Requirements

As in the case of the signal/target processor, the required complexity of the netting computer depends upon the number and type of sensors in the net. For the point sensors only case, a small microprocessor with a floppy disk mass storage device (such as that used in the FIDS system) will suffice. However, if one or more radars are included in the system, then a more powerful system is required. In this case, generally a 16 bit minicomputer of the NOVA or PDP-11 class with a hard disc would be required in order to perform all of the target association functions and provide the mass storage required for a high resolution color display. On three previously developed netted systems including LARIAT, the WIDS Target Detection Unit, and the MIT/Lincoln Laboratories netted radar, a NOVA 2 16-bit minicomputer has performed the function of the netting computer. Such machines are ideally suited for such a function since they are designed for high speed data handling. Furthermore, microcomputer versions of these machines are becoming available which will reduce the cost and increase the reliability characteristics of these systems. Finally, a MIL-qualified machine (the AN/YUK-19) is available which executes the NOVA instruction set.

E.2.3 DISPLAY PROCESSOR

E.2.3.1 Functional Description

The display performs two primary functions in the netted system: displaying target alarms and system messages and handling interactions with the operator. During initialization, images of the display background would be stored in the display memory so that different display images can be quickly changed on operator command. During operation, the display processor must receive target report updates and message information and generate the vector graphics commands to alter the display active memory. Also, operator inputs must be screened, and those involving display changes must be implemented, while those that involve system changes are passed on to the netting computer. To respond to alarms in real time, the display must be capable of changing displayed parameters rapidly, i.e., within one or two seconds after the occurrence of a change. If the detailed displays as discussed in Section 4 are to be created, then a large amount of on-line RAM memory will probably be required. In general, resolution high enough to allow the generation of primary base features and details of protected assets as well as color to increase the legibility of the display are highly desirable.

E.2.3.2 Hardware Characteristics

In order to be capable of displaying the types of features discussed in Section 4, the display hardware must include a high resolution (at least 512 X 1024 pixals) color output with the data stored in resident memory. One trick that has been used in previous systems involve storing the map features in two or three color planes of a display memory while animated features such as moving targets are stored in a fourth color memory plane. This allows the animated features which are rewritten often to appear to move on the display without erasing the map information. Thus, the map could be written from disc at turn on and stored in the blue/green memory planes while animated targets are written in the red/yellow memory planes resulting in a white color for the animated targets. In order to generate the vector graphics and respond to operator inputs, the display must include a microprocessor. The system memory would include PROM memory for display maintenance software, RAM memory for the displayed parameters, and RAM memory for system software. The RAM memory would be booted from the Netting Computer. A survey of available display hardware is summarized in Appendix C.

E.3 SUMMARY

In this Appendix, a brief overview has been given of the functional and hardware requirements of the digital processors needed for the Netted System. More details on the requirements can be obtained from system description documents prepared for the WIDS, TDU, and LARIAT programs.

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